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**A REVIEW OF METHODS AND EQUIPMENT
FOR THE MEASUREMENT OF RUN-OFF**

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A REVIEW OF METHODS AND EQUIPMENT FOR THE MEASUREMENT OF RUN-OFF

BY

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Hobart, Australia.

INTRODUCTION

1. Run-off may be defined as that part of the hydrologic cycle when water is present on the earth's surface. This paper is confined to the measurement of it in streams, an essential for accurate assessment of the amount available for use.
2. The measurement of stream flow is difficult. Measurement of water is subject to empirical laws and there is rarely a direct method of checking the accuracy of the work. It is necessary therefore to adopt the best available methods so that a standard of accuracy be attained that will provide reliable results. Past experience has shown that records of run-off, which are not of the highest quality, are more misleading than useful. Emphasis must therefore be placed on accuracy and reliability, every endeavour be made to adopt the best recognized procedures, and every precaution be taken to minimize those errors known to exist.
3. The basic principle of measuring run-off is that of inference, it generally being impracticable to make a direct measurement of the discharge of a stream. The method usually adopted is to make, and record, measurements of the discharge at various stream levels, sufficient to enable the relationship between level and discharge to be established. From this relationship, a rating table, or curve, is prepared giving the flow corresponding to all levels of the stream. This rating table is then applied to the record of river levels, with the result that a continuous record of flows in the stream is obtained. It is necessary therefore to relate the level of the stream to a fixed datum so that consistency of level readings can be obtained. This is usually accomplished by installing a suitable graduated gauge staff in the stream, from which the level of the river can be determined.
4. The relationship between the level of the stream and the discharge is controlled either by the physical characteristics of the stream in the vicinity of the gauge, or by some artificial structure, such as a weir. If this 'Control' changes, then the relationship between discharge and gauge level will also change. It is essential therefore to maintain a constant check on the relationship by a continuous programme of flow measurements.
5. The siting of a gauge station that is, a particular point on a stream where gauge readings are obtained and discharge measurements made to obtain flow records of the stream, involves some serious

considerations. Of these the most important is that there should be at the site that stability of relationship between gauge height and discharge that a 'control' may best provide. Sensitivity of the 'control' is important, if reasonably accurate results are to be obtained. The greater the rate of increase in gauge height in relation to flow, the more accurate the results. A site located in a pool or river section where the velocity is low will provide a satisfactory relationship. Access and cost are obvious, but should be subordinate, considerations.

WATER LEVEL RECORDING

6. Automatic recording by an instrument on a chart or tape is far better than that by the visual reading of a gauge set in the river, since:

(a) the gauging station may be located at the desired site, without regard to the availability of a gauge reader.

(b) A complete record of the behaviour of the river can be obtained. Daily readings, usually limited to one or two per day (except perhaps in the lower reaches of large streams), are insufficient to obtain the true average flow and other information, such as peak flows and times of peaks that are important in flood investigation.

(c) Gauge readers have too often been unreliable.

(d) A gauging station should be regularly visited by a responsible person to obtain flow measurements and to maintain the station in good order. As an automatic recorder requires periodic servicing, these regular visits must be made. The merely 'read' station tends to become neglected.

7. The operation and maintenance of automatic water level recorders by persons other than trained Staff Hydrographers has proved most unsatisfactory. Chart records have been found to be incomplete, and operation has been incorrect as to time and gauge height setting, the general standard of the records sometimes very poor. For staff operation, which will more than justify its cost, instruments requiring attention only three or four times each year should be used.

Instruments and Equipment

8. There are various types of instruments which will produce a decipherable record of water levels. The two types normally used are those which produce a graphical record of water level and those which produce a record in the form of a punched tape. The latter are in an early stage of development and apart from the fact that they do not provide a visible, easily checked record of gauge heights, they are not suitable without the provision of translators and computers. This type of instrument is more complicated to operate than a common graphic type. The most universal and satisfactory recorder in use is the simple graphical type. This produces a line representing stream levels in relation to time. The behaviour of the river, and of the recorder, is directly visible. A record of levels is produced that can be treated to obtain flows either by arithmetrical calculation or by the use of a discharge integrating instrument.

9. Recorders can be of the long period, monthly or weekly type. One long period and satisfactory type of graphic instrument, driven by a weight or special "Negator" spring, gives operation periods up to six months. Weekly and monthly spring or electric driven recorders are not recommended unless they can be serviced regularly by trained staff.

10. There are three general methods of recording water levels in graphical form; these are: (a) float and wire, (b) pressure, and (c) gas back-pressure. Of these, the float type of instrument is the most commonly used and gives the most accurate and reliable results. It is usually operated in a well connected to the stream by a pipe in such a way that the float will react to the changes in stream level. The float movement is then transmitted by the wire to a stylus that marks on a chart. Its advantage is that it is simple, easily maintained, and gives an open scale. The cost of the float well may however, be high. An instrument, the 'Surface Detector', suitable for the operation of a float in an inclined pipe actuates a standard float type of recorder, producing a standard levelgraph. It is operated electrically by batteries, and therefore presents some problems of operation and maintenance.

11. The pressure type is operated by a pressure cell located in the stream, varying pressures due to rise and fall of the stream being conveyed by a tube to the recorder where a pressure diaphragm operates a recording arm that records the pressure or water level variations on a chart. Its advantages are, low cost of installation and that the instrument can be placed at any convenient point on the stream bank and connected to the pressure diaphragm by a small tube. Its disadvantages are its limited gauge height scale and its inherent inaccuracy due to the necessary amplification through levers of the small movement due to pressure change.

12. The back-pressure type relies for its operation upon the pressure exerted by the head of water in the stream on gas bubbling at a uniform rate from a small nozzle located in the stream. This pressure is transferred back to the instrument through the small supply tube, and by using either a pressure cell or a manometer, the variations in pressure can be converted into gauge heights on a chart. As with the pressure type of recorder, the back pressure type is cheap to instal but, except where the expensive manometer type is used, the gauge scale is limited. Maintenance is important as gas leaks will put it out of commission.

Instrument Housing

13. In bad climatic conditions, where snow, heavy rain or extreme cold is encountered, the housing of the recorder should be lined and extensive enough to provide accommodation for the officer servicing the instrument; under moderate conditions sufficient to allow the officer to service the instrument under shelter, and in some instances lined. Suitable for mild climates where rain is not frequent or severe, shelters that accommodate the instrument only, may be of a round corrugated iron type, made to fit directly over the well, or a steel hinged top type which, when open for servicing, will provide some cover for the instrument. (See Figures I - IV).

Measurement of Discharge

14. It is accuracy of measurements of the discharge of a stream that determines the worth of the basic stream flow data. If it be not of high degree money and time spent on accurate recording of water levels and the other work involved will be completely wasted. The four methods commonly used to determine discharge are weirs, floats, slope measurement and current meter. Weirs, suitably calibrated are satisfactory; as their characteristics are well known, however, it is not proposed to deal with them here.

Floats

15. Floats can be used to estimate the velocity of a stream but should be regarded only as a secondary method of measuring discharge. They are used when more accurate methods are not possible, usually during floods. There are two requirements: a knowledge of the relationship between the velocity of the float and mean velocity, and a surveyed stretch of river giving cross-sections at regular intervals. The main difficulty is in determining the relationship between float velocity and mean velocity; this results in float discharge measurements being only approximate

Slope Measurements

16. Slope measurements can also be used to measure the approximate discharge of flood flows. A stretch of river is selected and cross-sections surveyed at various points. The slope of the water is measured, and Manning's formula, $V = \frac{1.486 s r^{2/3}}{n}$, is used where n = Manning coefficient, s = slope of water, and r = hydraulic radius, in feet. The velocity is applied to the mean cross-sectional area of the stream. The coefficient "n" is determined by measuring the flows at lower stages by a more positive means and applying an estimated value to the flood slope and section.

Current Meter Measurements

17. The normal method of stream gauging is the use of a current meter and will be treated in some detail. Basically, current meter discharge measurements are produced by measuring the velocity of the water with a current meter and applying that velocity to the measured area of the stream, e.g. in British units the product of velocity in feet per second by area in square feet results in the rate of flow in cubic feet per second units, (cusecs). The flow in cusecs at a point is therefore the volume of water in cubic feet passing the particular point every second. The distribution of velocity in a stream is such that it is necessary to measure the velocity in a large number of positions in the cross-section. Variations in depth across the section require water depthing at regular intervals to give an accurate measure of the area. The use of the current meter to measure velocity, consists in positioning the meter at the particular point in the section, and determining the rate of rotation of its moving wheel or propeller by timing a number of revolutions with a stop watch. From the calibration of the meter the relevant velocity can be determined.

18. Five methods of making these velocity and depth measurements can be used: wading, cableways, travelling pulley, bridge, and boats.

19. Wading. Where the depth and velocity of a stream are such that an observer can wade conveniently and make accurate measurements. It is normal for the observer to wade across the section, measuring depths and velocities at the various points. A marked cross line, usually $\frac{3}{8}$ " circumference flexible wire rope, is used to locate the measuring sections and at the same time to support the observer, if necessary, against the current.

20. Cableway. Where a stream is not suitable for wading, a cage and cableway to carry the observers across the stream in the making of the necessary observations, may be used. Normal practice is to have the current meter weighted with a lead weight and supported from a hand winch by a two conductor meter cable. The meter is in turn supported

in the direction of the stream by a stayline running on a cross line upstream of the main cable. Using the main cable as a distance marker, the cage is moved to the section required and the meter positioned in the section by means of the winch, wire and stayline. Meter revolution signals are transmitted to the cage via the meter wire where they are timed and the data recorded. This is a relatively accurate method because: (a) the best measuring site within the vicinity of the gauge can be chosen and eddies, interference from piers, and logs avoided; (b) the observers being in the cage directly above the meter, better control can be exercised in positioning it in the section, and the section across the stream can be more accurately measured; and (c) depthing can be done more accurately, as the meter and weight are on a direct line down from the winch.

21. Travelling Pulley. In this method the meter, complete with its lead weight, is moved across the stream supported on a wire strung across at the section. It is normally operated from one bank using an endless flexible wire to move a travelling frame carrying the meter along the cross wire. From the bank the meter and weight are raised or lowered by means of a two conductor meter cable, running through a pulley attached to the travelling frame. Positioning across the section is accomplished using the endless flexible wire, fitted with metal distance markers. This method is not recommended for accurate work. Depthing and meter positioning at a distance and the lack of a meter staywire tend to introduce errors. However, it is useful on small streams which are too deep to wade but too narrow to warrant a cableway.

22. Bridges. The use of bridges is limited for two reasons; they are not always at the site where measurements are required, and the conditions at bridge sites are often unsuitable for flow measurements. However, where a bridge is in the vicinity of the gauge and flow conditions are satisfactory, it can be a convenient and economical means of making discharge measurements. Two common methods used to support the meter and weight from a bridge are by a portable hand winch crane, and by a Land Rover crane. Where large bridge piers or debris interfere with the flow, use is made of a cross line strung a short distance from the bridge. From certain types of low level bridges, a rod (1 in diameter) can be used to support the meter. Very accurate results can be obtained in this way, particularly in canals. (Cranes are shown in Figures V and VI).

23. Boats. Where wide streams of moderate velocity are to be measured, boats can be used with considerable success, provided satisfactory arrangements are made to position the boat and handle the meter. In certain circumstances, anchoring of the boat can be carried out satisfactorily but additional work is required to calculate its position in the section.

Selection of Site

24. The desirable features of sites for making discharge measurements vary, depending on the type of measurement. For measurements using suspension methods, the main requirements are: measurable velocities at all ranges of flows (floods excepted), velocities reasonably steady and normal to measuring section, flow contained within one section, bed of stream reasonably even, site accessible to as high a flow as possible, and close to gauge. The downstream end of a pool usually provides a good site, for, as the flow decreases the velocities are maintained over the shallow section, whilst at higher flows the section generally becomes drowned out, resulting in velocities

keeping within reasonable limits. For wading measurements the site is usually selected by the hydrographer, as at low flows it is necessary to select one which suits the particular flow conditions. Sites which are very shallow or which have velocities below 0.5 ft per second should be avoided.

Measurement of Area and Velocity

25. Area measurements are usually made in conjunction with the velocity measurements as follows: velocity in the cross-section varies both in a horizontal and in a vertical direction, whilst the depth also varies across the section. It is necessary to divide the stream into a number of small sections and to make measurements of depth and velocities in each. The number of vertical sections to be adopted depends on conditions at the measuring site. A guide to the spacing of vertical sections is:

<u>Stream Width (ft)</u>	30' - 100'	100' - 150'	over 150'
<u>Width of Vertical Section (ft)</u>	5'	7' - 10'	10' - 20'

In all cases the first and last sections are taken as close as possible to the bank.

26. Where permanent facilities exist for suspending the meter, e.g. cableways, the depths across the section may be established either by levelling or by accurate depthing at low flow. These established depths, related to a gauge at the gauging site, serve as a check on depths obtained during a measurement and provide depths when accurate depthing is not possible.

27. For normal stream gauging work, sufficient observations are made in each vertical section to enable a curve of velocity against depth to be drawn. From this curve the mean velocity in the vertical section can be obtained by dividing the area under the curve by the depth. The number of velocity observations required in each vertical section varies with the depth; the following rules generally apply:

<u>Depth of Water (ft)</u>	0 - 1	1 - 3	3 - 6	over 6
<u>No. of Velocity Measurements</u>	1 - 2	3 - 4	4 - 5	6 - 10

Although this method takes somewhat longer than others, it is justified by its greater accuracy.

28. Sometimes it is not possible to carry out the full velocity method, owing to lack of time, rapidly rising or falling stage and the impossibility of getting the meter down to the stream bed. Under conditions such as these, measurements of velocity are made at 2/10 and 8/10 the depth, and the mean of the two readings is taken as the section mean. This assumption is based on the fact that vertical velocity curves approach a parabolic shape.

29. When it is not possible to get down to 8/10 depth, for example during floods, measurements of velocity are made at 2/10 of the depth. A correction factor, usually about 85% is applied to the 2/10 flow; 2/10 depth measurements are preferred to "surface" measurements, although "surface" measurements are usually taken at a depth of one foot. It has been found that during high flows, waves often make it difficult to keep the meter in the water at "one foot". Apart from the fact that 2/10 is a definite proportion of the depth, the meter is usually deep enough to remain under the surface. In depths of less than one foot, observations at 6/10th the depth, give

an approximate mean velocity.

INSTRUMENTS AND EQUIPMENT FOR CURRENT METER DISCHARGE MEASUREMENTS

Current Meters

30. The current meter is the instrument used to determine the velocity of the stream. Although types of meters, have been developed which indicate velocity directly, mostly electronic, the usual meter is of the inferential type, i.e. velocity is determined from the rate of turning (or angular velocity) of the moving part, when the meter is immersed in the moving water, the rate of rotation of the moving part being calibrated against the velocity.

31. The usual calibration method is to tow the meter through still water at a known velocity, and at the same time register the revolutions per second of the meter. This procedure is repeated for a number of different velocities to enable a relationship between revolutions per second of the meter and velocity to be established. This relationship can be derived either by drawing an average line through the calibration points, or by calculating the best equation by the method of least squares. A current meter should, be reliable in its operation, light, robust and easy to handle, maintain its calibration under various conditions, and suitable for the measurement of velocities over a wide range.

32. The two principal types of current meters in common use are the cup or bucket wheel and the propeller. The cup type meter consists of a number of cups mounted on a vertical shaft. Electrical contacts for revolution counting are located in a chamber fixed to the yoke of the meter at the top of the wheel shaft. Two contacts in the chamber allow for the registration of either single revolutions or every fifth revolution of the wheel. The propeller meter is one which can be recommended for all classes of water velocity measurements; it will resolve oblique currents. Various types of propellers can be fitted to suit velocity and conditions encountered. One firm provides plaster casts which fit the propeller and reveal any deformation of the blades which would cause a change in calibration.

33. For the measurement of low velocities for use in streams of shallow depths, special pygmy meters have been developed which will measure accurately down to 0.2 ft per second. The propeller type is the better for these purposes.

Ancillary Equipment

34. The use of winches for handling current meters in suspension methods is very desirable. Not only do they reduce the time required to make a discharge measurement, but they also permit the use of heavier weight, up to 150 lb. The type of winch will depend on the weight to be handled. The drum should be long enough to accommodate the full length of meter wire in one layer so that the measurement of drum rotation can be used for depthing, through the use of a revolution counter.

35. As the signal indicating current meter revolutions is normally made by the making and breaking of an electric circuit, the cable on which the meter is supported must also transmit the meter signal back

to the observer. It is necessary therefore to use a two conductor meter cable, i.e. one which has insulated core wire surrounded by a steel wire. A special connector is necessary to join the cable to the steel hanger supporting meter and weight.

36. The provision of a stay line to support the meter is of great assistance in keeping the meter in the section and in preventing meter surging and side-sway. The stay line has been found to operate easily and simply when attached to a free running pulley on a cross line erected some distance upstream of the measuring section.

37. Cableways can be double or single wire, depending upon the span. Up to 150 ft span single wire cableways are generally satisfactory, but for larger spans double wire cableways have advantages, such as greater stability, reduced sag and better distribution of meter loads, whilst the smaller size cable required can be handled and transported to the site more easily. Cableways should be designed and regularly tested in accordance with their particular specified procedure. Type of construction depends on the site. Rock bolt anchors, tree supports, ~~frame~~ supports and steel pole supports can be utilized. (See Figures VII and VIII).

DISCHARGE MEASUREMENT COMPUTATION PROCEDURES

38. Arithmetical Method. The basic assumptions of the method are that the mean velocity varies as a straight line between vertical sections in the stream, and the bed of the stream is a straight line between the vertical sections. There are two ways of applying it; the "mean" section method, and the "mid" section method. The mean section method consists of dividing the stream into a number of small sections by means of spaced vertical sections. The distances between the vertical sections are measured and the mean velocity in the vertical sections obtained. Each small section is then treated by halving the sum of its two end vertical section depths and multiplying by the width between vertical sections. This gives the area of the section. Mean velocity in the section is obtained by halving the sum of the mean velocities in the two verticals. The product of the mean flow and the area gives the discharge in the small section. The flow through each small section is then summed to give the total flow. The "mid" section method differs from the "mean" section in that observations of depth and velocity are used without averaging. They are made in the same manner and in the same vertical sections as the "mean" velocity method, but the values of depth and velocity at each vertical section are applied to a cross-sectional area whose width extends halfway to the preceding and following vertical sections. This method therefore eliminates the process of averaging depth and velocities in each section.

39. Summation Curve or Integration Method. The true value of a discharge through a section is found by integrating the flow through vertical sections of unit width. In the measurement of a stream this is accomplished by using the data obtained in the arithmetical method but the mean velocity in each vertical section is multiplied by its depth to give the discharge through a section of unit width. These values in ft per second units, are plotted vertically with horizontal spacings equal to the distances between the vertical sections. The area under the curve joining these values gives the total discharge.

40. Discharge Rating Curve and Table. The discharge rating curve.

which provides the relationship between stream water level and discharge, is one of the important factors governing the accuracy of flow records. It is essential that sufficient measurements be made at various discharges to obtain a reliable curve. Discharge measurements should be made at regular intervals of time to check the validity of the curve

41. Reduction of Flows. Automatic water level recorder charts can be treated arithmetically or by the use of a discharge integrator. When chart river levels are treated arithmetically it is usual to select sufficient readings from the chart to give the mean for the day. The mean is obtained by averaging the rating table flow value for each selected gauge height and not by averaging gauge heights. A mechanical integrating instrument similar in principle to a planimeter can be used with certain strip charts to give the mean flow for the day. By setting the instrument to the rating table values, and following the river level curve on the chart, mean value for the day can be read directly from the instrument.

42. Mean flow for the day at daily read stations is generally assumed to be the discharge equivalent for the gauge heights read. If more than one reading is made, the mean of the flow values should be taken. During floods many readings should be made and hydrographs plotted. From these the mean discharge for the day can be determined

43. Presentation of Flows. Daily flow tabulations are usually required. For hydro-electric system operation studies daily flows are necessary for computer calculations. Monthly flows should be tabulated in the form of maximum, minimum, mean and total for the month. Mean yearly discharges should also be tabulated. However, calendar year divisions do not always suit the climatic conditions of the site. To obtain a yearly period where run-off during one period does not affect the other, it is often necessary to create an artificial year, termed the "Water Year".

ANALYSIS OF RECORDS

44. Apart from the detailed analysis of records required for specific projects, there are a number of analyses that add to the value of the presentation of flow data. Hydrographs of daily flows are useful for determining the time elements of flood crests and flood maximization and for the checking of the water level recording instrument. The general plotting of these graphs is not recommended.

45. A mass curve is the summation of the hydrograph. The abscissae are in units of time and the ordinate at any point represents the total volume of flow up to that point. It enables a rapid analysis of the behaviour of the stream to be made, averages over various periods to be compared and trends to be noted, and provides information on the amount of storage required to maintain various flows. The residual mass curve is the most convenient graphical presentation. It is obtained by the plotting of the accumulated departures of flow during periods from the average flow for the total period of the curve.

46. Duration curves, which show the percentage of time the flow was equal to, or greater than, a certain value, can be calculated from daily flows. The curve can also be in the form of a percentage of the average flow.

47. The double mass curve consists basically of the plot of two hydrologic elements such as rainfall and stream flow, rainfall and rainfall, or stream flow and stream flow, in such a way that the summation value on one ordinate of one element for a period of time, e.g. a year, over a number of periods, corresponds to the summation element on the other ordinate. The result of the plot is generally a straight line of uniform slope. If one element is known to be reliable, a change in slope indicates an inconsistency in the other element and investigation of the inconsistent element may be justified. The double mass curve should be used to indicate possible inconsistency in records and not as an instrument of correction.

DISSEMINATION AND PRESERVATION OF STREAM FLOW RECORDS

48. Not only should the records of stream flows be made available generally; their availability should be made known. This can be done by regular publications of stream flow records and by the circulation of annual reports to interested bodies.

49. The value of run-off records obtained today, lies mainly in the future. It is the records themselves must be carefully preserved, and so also must the evidence on which they are founded for it is by this that the authenticity of the records can be established at any time. The longer the period of records the better will be the assessment of the country's water resources.

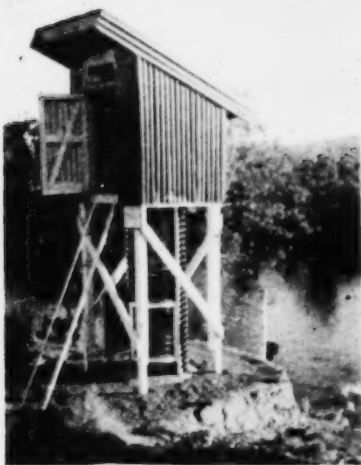


Fig. 1. Shed Type Recorder House Shelter.

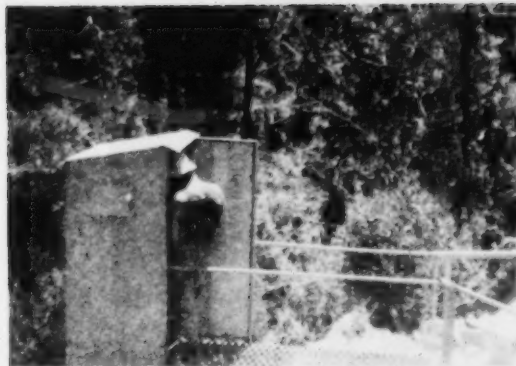


Fig. 2. Galvanized Flat Iron Shelter.



Fig. 3. Corrugated Iron Shelter.

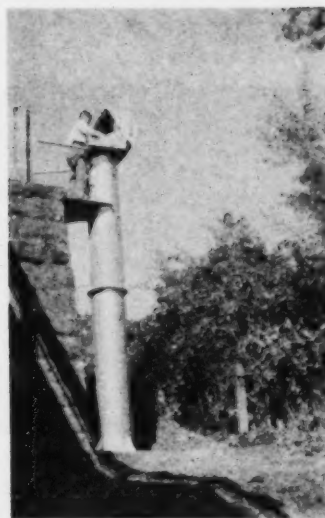


Fig. 4. Steel Hinged Top Shelter.

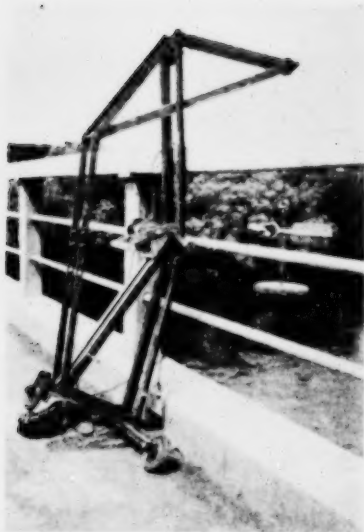


Fig. 5. Portable Bridge Crane.



Fig. 6. Land Rover Bridge Crane.



Fig. 7. Double Cableway.



Fig. 8. Single Cableway.



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CONFERENCIA DE LAS NACIONES UNIDAS
SOBRE LA APLICACION DE LA CIENCIA Y LA TECNOLOGIA
EN BENEFICIO DE LAS REGIONES MENOS DESARROLLADAS

Punto del programa : A.5.3.3

Argentina

PLANTAS MOVILES PARA CONCENTRACION DE MINERALES :
UN VALIOSO ELEMENTO DE DESARROLLO Y TECNIFICACION
PARA LA PEQUEÑA Y MEDIANA MINERIA

Por Laureano MUNIZ,
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Las monografías presentadas en la Conferencia de las Naciones Unidas sobre la Aplicación de la Ciencia y la Tecnología en Beneficio de las Regiones Menos Desarrolladas constituyen documentos de trabajo de dicha Conferencia. Se publican tal como han sido presentadas por los colaboradores y los puntos de vista expresados en ellas corresponden a los colaboradores. (Véanse notas al dorso.)

NOTAS

1. Las monografías seleccionadas para las Sesiones Generales serán distribuidas en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

2. Las monografías seleccionadas para las Sesiones Especiales serán distribuidas en la Conferencia únicamente en uno de los idiomas oficiales antes indicados.

3. Los resúmenes de las monografías presentadas por los colaboradores serán distribuidos en la Conferencia en los siguientes idiomas oficiales de las Naciones Unidas: español, francés, inglés y ruso.

4. No se procederá a la distribución general de las monografías y resúmenes con antelación a la Conferencia. Únicamente serán publicadas en cantidades limitadas con antelación a la Conferencia para uso exclusivo de las delegaciones de los gobiernos participantes y de otros participantes autorizados. La publicación con posterioridad a la Conferencia y la distribución general de las actas y debates de la Conferencia seguirán las prácticas de las Naciones Unidas establecidas por la Junta de Publicaciones de las Naciones Unidas.

PLANTAS MOVILES PARA CONCENTRACION DE MINERALES:
un valioso elemento de desarrollo y tecnificación para la
pequeña y mediana minería.

por Laureano Muñiz, Ing. Min., Prep. Min.

Instituto Nacional de Tecnología Industrial
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1. Introducción

Pese a que Argentina comparte con Chile la Cordillera de Los Andes a lo largo de unos 3.500km al oeste, y con Bolivia y Chile el vasto altiplano de la Puna al NO, parece no haber sido favorecida con los grandes depósitos minerales de sus vecinos. Del mismo modo, las formaciones orogénicas más antiguas también se mostrarían reticentes en brindar los yacimientos de la importancia de sus correspondientes en otras partes del continente.

Es posible que esta pobreza aparente obedezca a fundadas razones geológicas, que en todo caso están lejos de ser conocidas, pero sí se puede afirmar que la minería no ha recibido en Argentina la atención que su importancia requiere. Las extensas y fértiles planicies aptas para la agricultura y la ganadería acapararon por mucho tiempo los esfuerzos del país convirtiéndolo en una comunidad esencialmente agropecuaria.

La rápida industrialización experimentada en los últimos años introdujo serios desajustes o desequilibrios en aquella estructura económica y social, no siempre controlables en forma inmediata. Una de estas anomalías es la ascendente demanda de minerales y metales que en ningún momento fue satisfecha por la incipiente producción nacional. La importación de estas materias primas gravita cada vez más en la balanza del comercio exterior desde que la producción industrial es absorbida casi enteramente dentro del país.

La búsqueda de nuevos yacimientos y la explotación racional de las reservas minerales conocidas son los caminos obvios para reducir las importaciones de materias primas minerales y alcanzar un eventual autoabastecimiento. El primero, es un camino lento y costoso y no siempre coronado con el éxito, - que requiere relevamientos y prospecciones regionales de incumbencia estatal, y fuertes inversiones en las etapas previas a la explotación. La extracción y beneficio del mineral presenta, en cambio, características controlables en forma inmediata.

Una acción integral para estimular la minería es poco menos que imposible dadas las actuales circunstancias económicas del estado. No obstante pueden alcanzarse resultados significativos tecnificando las casi primitivas medianas y pequeña minería con miras a un aprovechamiento más eficiente de las magras

reservas minerales. Una sugerencia en este sentido, es la introducción del uso de plantas móviles de pequeña capacidad, integrables con equipos disponibles to talmente en el país, de bajo costo y de recuperación total.

2. Estado Actual del Aprovechamiento de los Recursos Minerales en el País (excepto combustibles)

Una breve consideración de los problemas y dificultades encontradas en nuestra minería permitirá evaluar las posibles soluciones y en especial las ventajas ofrecidas por las plantas móviles de tratamiento aquí sugerida.

De los cuatro grandes yacimientos metalíferos conocidos con reservas significativas, sólo dos están en explotación. Ellos son mina Aguilar (Pb, Zn) con una producción de 1.100 TPD perteneciente a una empresa americana, y minas de Zapla (Fe) con 450 TPD explotados por Fabricaciones Militares. El yacimiento de Sierra Grande (Fe) es propiedad de Fabricaciones Militares y el de Farellón Negro (Mn, Au) cuya propiedad es compartida entre el Gobierno de la Prov. de Catamarca y la Universidad Nacional de Tucumán, aún están en la etapa de exploración.

Si bien no son de significación internacional, estas minas escaparían a muchas de las consideraciones expuestas a continuación, las que concernirían esencialmente a la llamada pequeña y mediana minería.

2.1- La Minería Dentro de la Economía Nacional.

Según el tipo de la actividad extractiva y la naturaleza del mineral extraído, es común en Argentina clasificar a las actividades mineras en minería metalífera, no metalífera y de rocas de aplicación. (materiales rocosos y sedimentos utilizados en la industria de la construcción).

Las reservas de rocas de aplicación son abundantes y su explotación no ofrece dificultades a pesar de que muy frecuentemente no se usa una mecanización adecuada y su preparación aún se realiza con medios más bien primitivos.

Donde el déficit de materias primas minerales se advierte es en los metalíferos y no metalíferos, adquiriendo caracteres graves en los primeros. Para el año 1958, p.e., la producción alcanzó un valor de u\$s 12 millones, mientras que se debió importar por un monto cercano a los u\$s 265 millones superando el correspondiente de la importación de petróleo y sus derivados que en ese año llegó a u\$s 200 millones. En otras palabras, la producción nacional de minerales sólo representa el 4,5% de la demanda doméstica.⁽¹⁾⁽²⁾

Desde luego, estos valores no representan la situación real de las necesidades ya que, por diversas razones los consumos per cápita de los distintos metales están por debajo del de otros países de nivel cultural comparables. Si bien se han operado algunos cambios en favor de una reactivación de la minería, ésta se realiza a un ritmo lento y por debajo del crecimiento de las necesidades del mercado interno, observándose en algunos casos particulares más bien una retracción.

El área ocupada por montañas y formaciones favorables para las actividades mineras es de un 30% del territorio nacional.⁽²⁾ Para una buena parte de ella, la minería constituye la única posibilidad de incorporarse a la vida eco

nómica del país.

Las reservas minerales de las minas registradas son poco conocidas. Estudios previos incompletos y deficientes trabajos exploratorios no permiten hacer estimaciones con fundamento. Lo cierto es que los yacimientos con reservas significativas y convenientemente verificadas son poco más de diez. Los demás poseen reservas que van desde las 5.000ton. a las 50.000ton.

El subdesarrollo minero presenta pues caracteres críticos, no sólo por su incidencia en la economía nacional sino también por su gravitación social en una vasta porción de su territorio.

2.2- Características de las Faenas Mineras.

Infinidad de pedimentos mineros en que sólo unos pocos son trabajados irregular y esporádicamente, es el panorama predominante que se observa en la minería argentina. La mina, que generalmente está localizada en lugares más o menos inaccesibles (grandes altitudes, falta de caminos y largas distancias a líneas ferroviarias) y en un medio más bien riguroso (escasez de agua, clima desértico), es pequeña y se trabaja con medios primitivos.

En tales condiciones, antes de que se puedan extraer las primeras toneladas, el minero debe afrontar fuertes erogaciones, por lo que el mineral debe ser vendido sin demora para atemperar el efecto de las primeras inversiones. Como consecuencia sólo extrae de las labores y rajos únicamente las partes más ricas del cuerpo mineralizado adoptando los métodos de laboreo que solamente la seguridad más elemental le indica. Ello entorpece sensiblemente el normal desarrollo del yacimiento eliminando toda posibilidad de un aprovechamiento racional tanto en la extracción como en la preparación del producto a ser comercializado.

Dispositivos primitivos son comunes tanto en la extracción como en la preparación del mineral. El equipo mecánico cuyo uso está un poco más generalizado son los compresores y martillos neumáticos. La mediana minería, en cambio, aparece mejor dotada mecánicamente, aunque presenta serios problemas principalmente en la preparación mineral por fallas técnicas de ingeniería y conducción de las operaciones.

2.3- Causas Determinantes de la Actual Situación Minera.

Los factores de orden económico que conforman el cuadro minero son múltiples y complejos. Las grandes erogaciones propias de las etapas iniciales del desarrollo es el obstáculo más difícil de vencer antes de tener la chance de vender las primeras partidas de mineral. Estas inversiones se ven aumentadas desproporcionadamente por los altos costos de una planificación deficiente o por la escasez o ausencia de equipo mecánico. Estas circunstancias colocan al negocio minero en un nivel de vulnerabilidad demasiado peligroso como para estimular las inversiones del capital común.

La localización de áreas favorables para determinados yacimientos y la eventual localización de cuerpos mineralizados están entorpecidas por la carencia de los relevamientos regionales básicos. Todos los hallazgos han sido casuales, efectuados por personas sin conocimientos especializados, por lo que la propiedad minera adquirió un carácter individual, poco inclinado a pedir el con

-curso técnico.

El aprovechamiento subsiguiente del depósito se realiza con medios primitivos y con miras a una rápida comercialización del mineral, con una preparación manual o usando dispositivos tales como maritatas, canoas, chuas, etc. Las características de un producto tal, están lejos de ser, por supuesto, constantes y frecuentemente se ven paralizados por diferencias con las especificaciones comerciales.

Finalmente, una política oficial de precios de aquellos minerales de exportación no ajustables a la realidad en ciertos momentos, y disposiciones legales un tanto anticuadas han constituido trabas para una rápida y compensativa evolución minera acorde con la creciente necesidad de minerales.

3. Plantas de Concentración de Minerales Móviles Susceptibles de ser Usadas por Pequeñas Empresas Mineras

Una contribución para incrementar la producción de materias primas minerales lo constituye, sin lugar a dudas, el uso de pequeñas plantas de concentración por la pequeña y mediana minería. Dicha experiencia ha sido realizada en otros países latinoamericanos (Méjico) y aún en otros más desarrollados (EE.UU.) con excelentes resultados. Este equipo habilita al pequeño empresario a proseguir con el desarrollo del depósito mineral racionalmente a la vez que obtiene la información técnica indispensable para una eventual operación posterior en gran escala, siempre dentro de una evolución económica sólida.

Las plantas móviles son totalmente desconocidas en la minería argentina. Equipos de esta naturaleza son usados únicamente en canteras y ripieras para el tratamiento de material para la construcción y para obras viales, y son bien conocidas las ventajas de su operación a pesar de que sólo están compuestos de trituración y cernido en tromeles.

Las características de las plantas aquí sugeridas se apartan muy poco de los diseños comunes, ajustándose aquéllas a las condiciones locales más bien que al material a tratar. Estos equipos forman unidades compactas, totalmente independientes y absolutamente recuperables. Las instalaciones de servicio son reducidas al mínimo e integran la unidad dentro de las posibilidades.

Se considerarán dos tipos de plantas: Se designará como plantas portátiles aquéllas unidades montadas sobre chasis y ruedas remolcables con un camión standard (acoplado o semiacoplado). La capacidad estaría entre 10 a 30 TPD.

Las plantas móviles serían las unidades montadas sobre estructuras metálicas, las que serían ancladas a cimientos de mampostería. El flow-sheet sería más elaborado que el de las plantas portátiles, sujeto a las condiciones particulares de la mena a tratar. Por otra parte la capacidad también sería mayor, pudiendo llegar hasta 100 TPD según sea complejidad y tipo de tratamiento.

3.1- Plantas Portátiles.⁽³⁾

La versatilidad de operación y de ubicación, la reducida capacidad y el bajo costo de las plantas portátiles las hacen particularmente adecuadas para la pequeña minería. Estas unidades pueden entrar en operación desde los primeros pasos de la apertura del yacimiento tratando y recuperando el mineral extraído de las labores de exploración y preparación, o tratan viejos relaves

cuyo volumen no justifica una planta mayor.

Las características sobresalientes de estas unidades son las siguientes:

- a) El costo inicial es relativamente bajo; el número de máquinas requerido es mínimo, todas ellas fabricadas en el país o pueden ser compradas de segunda mano con cierta facilidad.
- b) La recuperación del equipo es total, desde que está montado sobre chasis de fácil y rápido traslado. Puede circular por caminos mineros y en algunos casos (semiacoplado) incluso por sus propios medios.
- c) Su armado requiere los conocimientos de un oficial mecánico, aunque es preferible una asistencia técnica superior. El grupo electrógeno puede adquirirse completo o armarse con un motor de camión u otro similar de 50HP cña, y un generador adecuado.
- d) El trabajo de operación de la planta sólo requiere la atención de una persona.

Entre las ventajas emergentes de su aplicación se puede mencionar que los productos reunirán las especificaciones comerciales, las que serán mantenidas a lo largo de las sucesivas entregas. La posibilidad de contar con mineral vendible desde los primeros pasos del desarrollo minero, amenguará sensiblemente el impacto de las primeras inversiones. El aprovechamiento del depósito mineral será comparable con el de establecimientos industriales de mayor capacidad, pudiéndose aprovechar eventuales subproductos en procesos posteriores a costos ínfimos, perdidos en la actualidad para la economía del país.

En el aspecto técnico, la incorporación de estas unidades permitirá una gradual tecnificación de las operaciones mineras mediante la contundente razón de beneficios económicos inmediatos. La posibilidad de una extracción global (partes ricas y pobres) facilitará el complicado y riesgoso procedimiento de práctica común hoy. Por último, un tratamiento anticipado en escala semi-industrial permite la recolección de datos sobre el comportamiento metalúrgico de la mena para una eventual operación industrial.

3.2- Flow-sheets y equipos.

Las Figuras I-V muestran varios flow-sheets posibles para plantas portátiles. En todas, excepto la Figura V, se prevé una sección de reducción de tamaños y clasificación en circuito cerrado (Figura I) en donde se puede instalar una zaranda vibratoria para aumentar la capacidad de la trituradora o mejorar la trituration.

La maquinaria que integra esta sección es la siguiente:

1 Trituradora a mandíbulas 5"x6"	500kg	5 HP
1 Elevador a canchales 4"x6"	300kg	1 HP
1 Tolva metálica 5'x6'x5'	350kg	-
1 Alimentador a cinta 3"x6"	200kg	1/4HP
1 Molino cónico a bolas 3'x36"	2000kg	15 HP
Carga de bolas	1000kg	-
1 Clasificador espiral 12"x10'	750kg	1 HP
	5100kg	22 HP

Las secciones subsiguientes del flow-sheet dependerá del mineral a ser tratado y su estado de agregación. Los sulfuros metálicos, p.e., podrán ser flotados globalmente en un circuito tal como el indicado por la Figura III, o bien intentarse la obtención de un concentrado de una especie (galena) y otro concentrado global (blenda, calcopirita, pirita, etc.), a ser tratado posteriormente, como lo señala la variante punteada de la misma Figura. Este circuito - también es apto para flotación de menas oxidadas y no metalíferos.

Ciertas asociaciones comunes de minerales metalíferos y no metalíferos, tales como sulfuros y baritina, fluorita, etc. pueden beneficiarse integralmente mediante circuitos mixtos de flotación y gravitación, tal el caso ilustrado en las Figuras III.

Un flow-sheet simple, apto para una recuperación global de minerales pesados, se ilustra en la Figura II. La capacidad de este circuito enteramente gravitacional, es relativamente grande.

Las maquinarias incluidas en estos circuitos son:

Jig diafragma simplex	8"x12"	200kg	$\frac{1}{2}$ HP
Jig diafragma duplex	8"x12"	450kg	$\frac{3}{4}$ HP
Celda de flotación unitaria	16"x16"	400kg	1HP
Banco de 4 celdas de flot'n.	16"x16"	1000kg	2HP
Mesa de concentración	14'9"x5'11"	2000kg	1 $\frac{1}{2}$ HP(fuera de chasis)

Para el tratamiento de depósitos aluvionales de minerales metalíferos, tal es el caso de arenas titaníferas de las playas atlánticas de la Prov. de Buenos Aires, el circuito indicado por la Figura V constituyó una solución que ha dado excelentes resultados en otros países.⁽⁵⁾ Sus características principales son la sencillez del proceso, la baja energía necesaria y la gran capacidad. La clasificación previa se hace con trommel. Los concentrados (caso de las arenas titaníferas) pueden ser retratados con medios magnéticos para una separación mineralógica.

Las maquinarias y equipos auxiliares incluyen bombas de distintos tipos, filtro a discos con bomba de vacío, a ser instalados dentro del chasis, e instalaciones para la disposición y retratamiento de colas, agua de cabeza, es pesamiento, etc., a ser colocados fuera del chasis.

El grupo electrógeno puede incluirse dentro del chasis siempre que las vibraciones o el ruido no afecte la operación de la planta. Su potencia po drá ser de 50 a 60HP como mínimo.

El peso total de la unidad sobre el chasis dependerá del circuito adoptado, pero se puede estimar que estará entre 7 y 10ton.

3.3- Plantas Móviles.⁽⁴⁾

Frente a la gran versatilidad de las plantas portátiles, las plantas móviles son más estacionarias aunque éstas requieren sólo escasos movimientos de tierra y fundaciones para su montaje. Las instalaciones auxiliares fuera de estructura, son más completas. Por esta razón las plantas móviles tienen aplicación a aquellos yacimientos cuyas reservas le aseguren una operación continuada de un mínimo de 10 años para permitir una cómoda amortización de aquellas obras no recuperables.

El diseño de estas plantas es algo más elaborado que el de las portátiles y permite hacer separaciones verdaderamente industriales. De capacidades superiores a 40 ó 50 TPD, pueden constituir la solución final para el beneficio de un depósito mineral de reservas conocidas moderadas, o servir de planta regional para un grupo de pequeñas minas ubicadas en las proximidades.

Como en el primer caso, las plantas móviles constituyen verdaderas unidades compactas. La maquinaria de las distintas secciones del circuito están montadas sobre estructuras metálicas, totalmente recuperables. Según sea el tamaño, estas secciones se pueden trasladar montadas. Las operaciones de montaje y desmontaje requiere la dirección de un técnico especializado.

Plantas de este tipo han ganado general aceptación en otros países - llegando a capacidades tales como 100 TPH (medios densos para lavado de carbón). En Argentina, satisfaría las necesidades de la gran mayoría de las minas llamadas medianas. La operación requiere escaso personal, tres en la mayoría de los casos.

Cualquier tipo de mena podrá ser tratado, en general, con estas plantas. El tamaño de las máquinas son industriales, y los costos de producción también podrán considerarse industriales por lo que habría posibilidades de acceso al mercado exterior de aquellas sustancias exportables, tales como berilo, uranio, wolfram, tierras raras.

Los flow-sheets más comunes incluirían: medios densos, para hierro, fluorita, baritina, y eventualmente carbón; gravitacional, para minerales pesados; flotación, para sulfuros, menas oxidadas, etc.; circuitos compuestos, para separaciones más elaboradas; separación magnética, para hierro y otras sustancias magnéticas. El tratamiento de menas auríferas requerirá un estudio separado previo, para determinar la viabilidad de una planta de cianuración de este tipo, por las excesivas instalaciones auxiliares fuera de estructura, requeridas, y el volumen de ciertas unidades.

4. Influencia del Uso de Plantas Móviles en la Reactivación Minera Argentina

Las ventajas económicas derivadas del empleo de estos equipos son obvias. El tratamiento es tan primitivo y depende tanto de la mano de obra que los altos costos eliminan de toda posibilidad a un gran número de yacimientos que, de otra forma constituiría una fuente de trabajo y de estabilización social en las zonas más pobres del territorio.

La tecnificación se introduciría en la forma más efectiva en un sector naturalmente reactivo a innovaciones aparentemente complicadas y de resultados inciertos. Por medios de pequeñas plantas, el pionero y las técnicas modernas de beneficio entrarían en contacto, y aquél aprendería a servirse de éstas en una medida cada vez mayor con las correspondientes ventajas económicas para la comunidad.

Una acción generalizada en este sentido permitiría no sólo una mayor disponibilidad de materias primas minerales en un plazo relativamente corto, - sino que la actividad privada tomaría sobre sí, la tarea de reactivar manifestaciones minerales autofinanciadamente, en forma e intensidad, por caminos clásicos de la localización de posibles grandes depósitos minerales.

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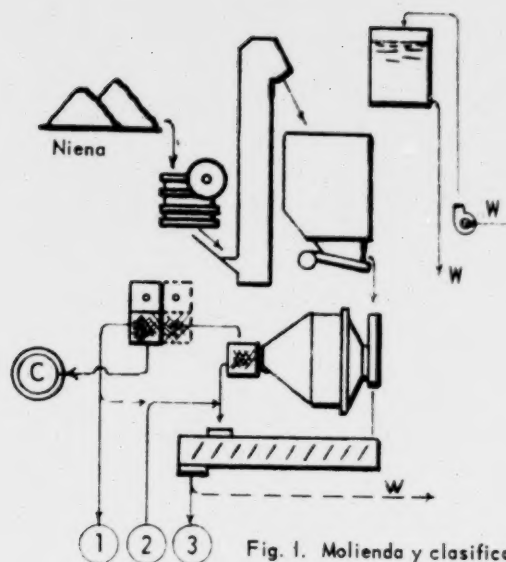


Fig. 1. Molienda y clasificación

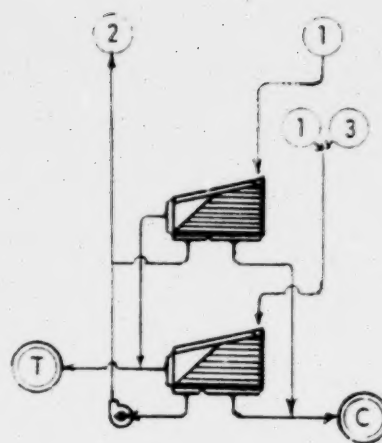


Fig. 2. Concentración gravitacional

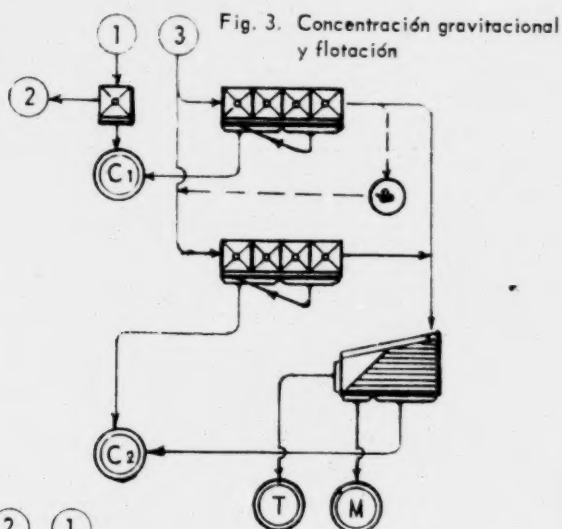


Fig. 3. Concentración gravitacional y flotación

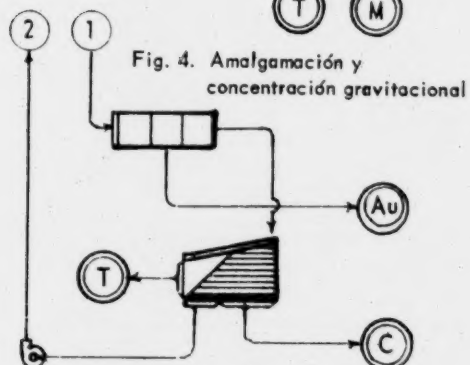


Fig. 4. Amalgamación y concentración gravitacional

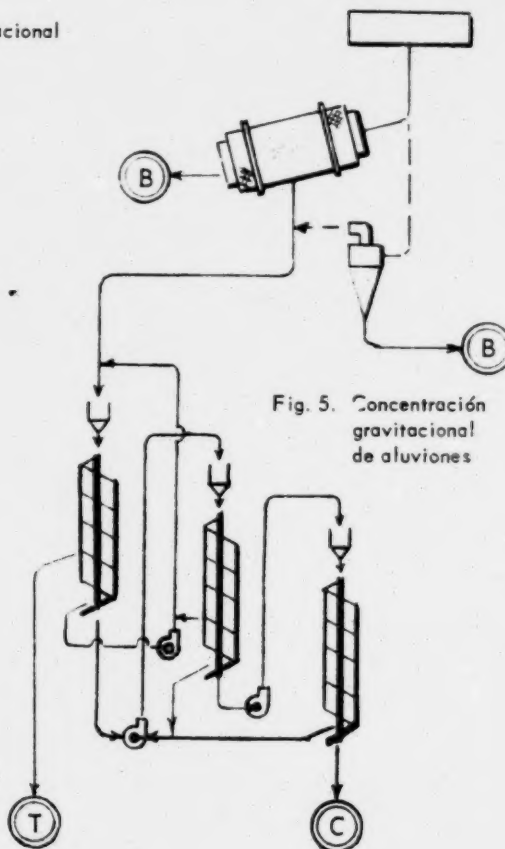


Fig. 5. Concentración gravitacional de aluviones

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NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.
2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.
3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.
4. Préalablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

La Station Météorologique Automatique
et ses applications dans les pays
en voie de développement

par A. PERLAT

1. L'intérêt de la Météorologie pour la mise en valeur des pays en voie de développement n'est plus à démontrer. D'autres que moi ont souligné l'intérêt de l'assistance météorologique dans de nombreux domaines de l'activité d'une nation :

navigation aérienne et maritime

préparation rationnelle de certains grands travaux grâce :

- à la connaissance du régime des pluies pour la détermination de l'emplacement des barrages, ou pour celle des périodes de navigabilité des rivières (transports de bois par exemple)
- à la connaissance du régime des vents, les précipitations, de la température, pour la préparation des plans d'urbanisme (régions à inondations notamment)
- aux études climatologiques qui permettent d'envisager l'implantation de nouvelles cultures, de connaître les possibilités d'utilisation de l'énergie solaire et éolienne.

La prévision du temps est utile pour l'exploitation des industries, pour l'agriculture, l'exploitation forestière, la pêche, l'élevage, les transports etc...et, d'une façon générale, pour toutes les activités soumises aux fluctuations atmosphériques, ainsi que pour la sauvegarde des vies humaines dans le cas des tempêtes et des cyclones.

Une importance particulière de la Météorologie est la lutte contre la faim, par la prise en considération des conditions météorologiques favorables ou défavorables pour la préparation des terrains (assèchement ou irrigation), lutte contre les ennemis des cultures (lutte anti-acridienne) et contre certaines maladies dont le déclenchement ou l'évolution sont liés aux facteurs météorologiques.

La connaissance passée, présente ou future de l'état de l'atmosphère est obtenue à partir de l'observation dans un réseau de stations dont la densité est en principe suffisante pour obtenir par "échantillonnage" une image synoptique du temps, d'un certain nombre de données : valeurs au sol et en altitude et variation dans le temps de la pression, de la température et de l'humidité de l'air, du vent; quantité, hauteur, nature, direction et vitesse des nuages; insolation; visibilité; précipitations sous toutes leurs formes (eau, neige, grêle); phénomènes accidentels (orages, tempêtes de sable, etc.) ainsi que la température superficielle du sol ou de la mer.

La détermination rationnelle de la densité nécessaire des mesures est un problème difficile dont l'étude confiée par l'Organisation Météorologique Mondiale (O.M.M.) à un groupe d'experts est en cours. D'après l'expérience acquise dans le tracé des cartes du temps, l'OMM recommande l'établissement d'une station tous les 100 à 150 kilomètres pour les besoins internationaux. A ce réseau de stations, il faut ajouter celui qui est nécessaire pour les besoins spéciaux ou nationaux, stations climatologiques, stations de montagne etc., composé en partie de postes auxiliaires, où des observations réduites sont faites par du personnel non spécialiste qui a reçu une instruction donnée par des météorologistes (ex: usine hydro-électrique, gendarmeries).

Le réseau d'observations météorologiques doit s'étendre aux régions désertiques ou peu accessibles. Il doit fonctionner en permanence même si on ne peut

affecter qu'un personnel réduit dans certaines stations. Pour cette raison, ont été construites des Stations Météorologiques automatiques capables, sans l'intervention d'aucune personne, de transmettre à distance, à heure fixe, par radio télégraphie ou par fil, sinon une observation complète, du moins des renseignements susceptibles d'être mesurés.

Les premiers équipements de ce type furent utilisés pendant la deuxième guerre mondiale. C'est en effet pendant cette période que les Russes installèrent les premières stations automatiques terrestres dans le désert de GOBI et que les Allemands exploitèrent des bouées automatiques dérivantes qui leur fournirent des indications sur les conditions météorologiques régnant sur l'Océan Atlantique, la Mer du Nord et la Manche.

Plusieurs pays se sont intéressés depuis, à ce problème et actuellement plusieurs réalisations sont exploitées couramment.

2. L'idéal serait évidemment de recevoir à partir d'une station automatique toutes les données qui figurent dans une observation complète du temps. Mais une difficulté intervient, car pour certaines de ces données, il n'existe pas d'éléments sensibles. La pression, la température, l'humidité relative, la vitesse et la direction du vent, la quantité d'eau tombée depuis un certain temps, la pluie à l'instant de l'observation, sont des données dont la télé-mesure ne souffre pas de difficultés car on possède des éléments sensibles dont les mouvements peuvent au moyen de leviers et d'aiguilles être traduits en signaux par un dispositif de télémessure. On peut envisager une transmission de la nébulosité en utilisant un héliographe, les indications d'une cellule photoélectrique, ou peut-être des détecteurs utilisant le rayonnement infrarouge émis par les nuages. La présence d'un orage dans les environs de la station, au temps présent ou au temps passé, peut-être indiquée par un indicateur d'orage. Mais la visibilité, le plafond et la nature des nuages, celle des précipitations, semblent plus difficile à transmettre par un équipement abandonné à lui-même, sans surveillance.

La technique permet d'obtenir une mesure automatique de la visibilité ou de la hauteur des nuages; de nombreux appareils donnant ces informations, à la fois par la lecture d'un cadran et par enregistrement sont en service dans différents pays, mais ces appareils demandent un entretien et des réglages relativement fréquents, donc la présence de personnel, et la consommation de courant électrique nécessaire à leur fonctionnement est élevée.

Le problème de l'alimentation en énergie d'une station météorologique automatique est l'un des plus importants et les possibilités locales en énergie conditionnent le choix du type de station.

Les dispositifs d'alimentation utilisés dans les stations automatiques sont très divers. L'alimentation des stations alimentées par un réseau de distribution d'énergie électrique ne pose pas de problèmes particuliers et les dispositifs employés sont tout à fait analogues à ceux utilisés pour l'alimentation de tout autre appareillage électrique. Il n'en est pas de même pour les stations isolées pour lesquelles la durée maximale de fonctionnement sans visite reste le plus souvent subordonnée aux performances des dispositifs d'alimentation.

L'alimentation la plus simple qui puisse être envisagée pour ces stations comprend une batterie d'accumulateurs ou de piles sèches. A chaque visite de la station la batterie de piles sèches est remplacée, ou la batterie d'accumulateurs est rechargée au moyen d'un groupe électrogène mis en route par le technicien chargé de l'entretien de l'équipement. Ce système n'est valable que pour les stations transmettant peu d'information, au moyen d'un émetteur de faible puissance. Pour les stations plus importantes restant isolées plusieurs mois, les groupes électrogènes et les aérogénérateurs sont les sources d'énergie les plus couramment utilisées.

Pour limiter la charge de la batterie lorsque l'aérogénérateur fournit un excès d'énergie, plusieurs procédés ont été utilisés. Parmi ceux-ci on citera les dispositifs à relais de tension qui placent l'aérogénérateur hors circuit lorsque la tension aux bornes de la batterie atteint la tension de charge maximale. Ces dispositifs sont malheureusement d'un fonctionnement assez délicat et n'ont pas toujours donné entière satisfaction. On peut également interposer entre la batterie et l'aérogénérateur un compteur ampère-heure-métrique qui établit à tout instant le bilan charge-décharge de la batterie, en tenant compte du rendement de celle-ci. Lorsque la charge atteint sa valeur limite, l'aérogénérateur, comme dans le précédent système, est mis hors circuit.

Le compteur ampère-heure-métrique est également utilisé à couper la liaison station batterie lorsque la charge de celle-ci devient insuffisante.

Certains aérogénérateurs équipant les stations automatiques sont équipés d'un dispositif de protection contre les vents forts. Celui-ci comprend un système centrifuge qui déclenche un frein dès que la vitesse de rotation de l'hélice dépasse une limite fixée lors de l'installation de la station. Un réenclenchement manuel de ce frein est alors nécessaire pour la remise en fonctionnement de l'équipement.

L'URSS et la France utilisent couramment des stations automatiques alimentées par aérogénérateur.

L'énergie solaire peut également être envisagée comme source d'énergie susceptible d'alimenter les stations automatiques. L'expérience dans ce domaine reste cependant limitée et les informations sur ce sujet sont encore rares. On peut cependant citer l'utilisation à titre expérimental de piles solaires pour l'alimentation d'une bouée automatique des USA. Toujours aux USA une réalisation a été faite pour utiliser l'énergie atomique.

Quel que soit le mode d'alimentation adopté il est souhaitable que le système de télémesure utilisé donne une transmission d'une durée aussi courte que possible. En effet d'une part les stations automatiques seront normalement groupées en réseau et une seule station de concentration aura la charge de rassembler leurs indications. Pour conserver le caractère synoptique du réseau, il faudra donc concentrer cinq ou six stations en moins d'une demi-heure. Or, il est indispensable pour avoir une sécurité de transmission de faire répéter trois fois le message de la station et il est encore nécessaire de séparer d'une minute ou deux au moins l'heure d'émission de chaque station pour éviter l'emploi de plusieurs fréquences et de plusieurs récepteurs; dans le cas où les horloges de commandes se dérègleraient. D'autre part, plus la durée de fonctionnement de la station automatique sera réduite, plus sera faible la consommation d'énergie.

3. Plusieurs types de stations automatiques existent dans le monde réalisées en Allemagne, en France, aux USA, en URSS et au Japon. À titre d'exemple nous allons donner une description d'un modèle construit en France (par la Société Industrielle de Télécommande et Télémécanique) transmettant à heure fixe (par exemple toutes les 3 heures) : indicatif de la station, pression atmosphérique, température, degré d'humidité, vitesse et direction du vent, quantité de pluie tombée depuis l'observation précédente, indication de présence de pluie au moment de la transmission. L'appareil peut être abandonné à lui-même pendant de longues périodes, de l'ordre de six mois; son alimentation et sa consommation ont donc été prévues en conséquence.

Les instruments météorologiques utilisés sont des enregistreurs classiques dont le tambour a été remplacé par un dispositif assurant la traduction en signaux électriques de la valeur indiquée. Chaque chiffre à transmettre est associé aux plots d'un collecteur; à l'instant de la lecture, un palpeur applique sur le collecteur le style de l'instrument dont le mouvement reste

libre entre deux lectures. Chaque plet du collecteur relie le relais de manipulation de l'émetteur radio à la batterie à travers un circuit constitué par un balai frottant sur une came. Cette came est découpée selon le signal Morse qui traduit le chiffre à transmettre par le plet associé. Le contact entre le style et le collecteur est assuré pendant la durée d'un tour complet des cames de manipulation. Les appareils dont la donnée est transmise avec deux chiffres significatifs (baromètre, thermomètre, hygromètre) sont associés à deux collecteurs fixes, l'un qui fournit le chiffre des dizaines, l'autre le chiffre des unités; l'échelonnement de ces chiffres au cours de la transmission est assuré par deux lignes de balais distinctes (l'une pour les dizaines, l'autre pour les unités) venant frotter sur les mêmes cames de manipulation.

Le pluviomètre et l'anémomètre sont associés chacun à un totalisateur, qui enregistre la somme des impulsions survenues au cours d'une période d'intégration déterminée (une par 65 tours du moulinet d'anémomètre et une par basculement des augets du pluviomètre).

Le totalisateur pluviométrique fait la somme de toutes les impulsions survenues entre deux émissions successives, c'est-à-dire au cours d'une période qui est normalement de 3 heures, tandis que le totalisateur d'anémomètre a pour période d'intégration les 10 minutes qui précèdent une émission. Cette période est simultanément utilisée par le pluviomètre pour fournir l'indication de pluviosité présente: si un balculement d'auget survient au cours des 10 minutes qui précèdent immédiatement l'émission, un signal spécial est transmis, un autre signal, indiquant l'absence de pluie, étant également transmis si aucun basculement n'a eu lieu au cours de cette période de 10 minutes.

La station automatique est alimentée par accumulateurs; elle ne nécessite donc aucune adduction permanente d'énergie, l'entretien se réduisant à la recharge des batteries (qui peut être effectuée automatiquement par génératrice solienne ou par groupe électrogène à démarrage automatique). En outre, les indications diffusées à heure fixe par voie radioélectrique ne demandent aucun matériel de réception spécial et peuvent, au moyen d'un code très simple, être interprétées par un personnel peu spécialisé.

Un horo-contacteur commande la mise en marche de la station. Cet organe est le seul qui fonctionne en permanence; son alimentation est assurée par des piles d'une durée de marche supérieure à un an.

Les ondes radioélectriques utilisées étant décamétriques, on sait que la propagation dans cette gamme présente des différences appréciables entre le jour et la nuit: la station renferme donc deux émetteurs, réglés sur deux fréquences différentes, de telle sorte que l'horocontacteur, qui définit le programme d'ensemble de la station, puisse actionner un émetteur différent selon l'heure de chaque émission.

Un moteur, actionnant un système de cames, assure la succession automatique des fonctions accomplies à chaque émission de la station, la commande initiale étant fournie par l'horocontacteur. Une émission occupe une période de 150 secondes, au cours de laquelle des signaux sont effectivement émis pendant 125 secondes. Les 50 premières secondes d'émission constituent la période d'appel, qui permet au correspondant de régler son récepteur sur l'indicatif fixe émis par la station; les 75 dernières secondes permettent la répétition à 3 reprises des résultats de mesure obtenus par les appareils météorologiques associés.

Les deux émetteurs radioélectriques, à ondes entretenues d'une puissance HF de 40 W couvrent l'un la gamme de 3 à 5 Mc/s (de 100 à 60 m. de longueur d'onde); l'autre la gamme de 6 à 8 Mc/s de 50 à 37,5 m).

Bien qu'il soit difficile de parler de portée limite en ondes pures décamétriques, l'expérience prouve que d'excellentes réceptions étaient couramment obtenues à des distances supérieures à 1.000 km.

Environ 30 Stations automatiques de ce modèle (fabriqué en France par la SITT) sont en service ou en cours d'installation dans le monde: France, Espagne, Inde, Australie, Sahara, Madagascar; régions polaires).

4. Grâce aux équipements, tel que celui qui vient d'être décrit, ou à d'autres modèles, il est donc possible de réaliser un réseau d'observations météorologiques même si on ne dispose que d'un très faible effectif de personnel spécialisé. Ces équipements qui résolvent à la fois le problème du personnel et le problème de la transmission des renseignements semblent donc convenir particulièrement dans les pays en voie de développement. En effet dans ces pays, les circuits de télécommunication ne sont pas encore suffisamment développés, la formation de techniciens en nombre suffisant pour remplir les diverses tâches nécessaires au développement du pays peut demander un assez long délai. Par ailleurs, des équipements se prêtent à l'installation de stations dans des régions actuellement déshéritées encore peu ou pas habitées et dont on veut étudier la possibilité de peuplement et de mise en valeur.



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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.4.3.2

Turkey

THE APPLICABILITY OF NUCLEAR POWER
IN LESS DEVELOPED AREAS

By Mustafa N. PARLAR,
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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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The Applicability of Nuclear Power in Less Developed Areas
by

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Dean, School Of Engineering

Middle East Technical University

1- General:

(a) Fortunately the problem of application of nuclear energy cannot be separated into categories as problem for fully developed countries, and under developed countries as far as the technical part of the application is concerned. The problem has the similar conditional requirements which based mostly on the economical situation of the country which may plan to use nuclear power for her industry or for domestic use.

(b) The load forecasting for the countries could be the best criteria in making decision if the nuclear power will be used at a given specific time. This means that the total energy sources of the country, developed or not, will be assessed and their worth of utilization must be evaluated on the basis of the present and possible forecastable future cost of the power of all possible natural resources, if nuclear power is found to be more economical than the others, then it will be the major criteria in policy making decision for energy development efforts.

(c) The international agencies have already made several investigations on the power resources of the world and the under developed countries are trying to assess the raw materials and resources of their countries as accurate as possible in order to make intelligent decisions for the development of their power system. In fact, only on the basis of such studies enough data will be collected for engineers, scientists, and economists for finding the optimum solution to the power development problems.

(d) the studies made by various under developed countries indicated that within the next fifty years there will be justification to use nuclear power¹. It is therefore necessary for the lesser developed countries to be prepared for such an event by training, operating, and planning personnel for nuclear power development. Happily, most countries now have some kind of research reactor which could be used to train technical personnel for their future needs. The International Atomic Energy could co-ordinate their effort by helping these countries.

(e) The problem of development of the nuclear power plant studied for Turkey indicated that a country which possesses very large hydro potential as well as conventional fuels may justify to have nuclear power for industrial and commercial uses if the load growth follows the predicted path and the cost of the nuclear power becomes competitive with the conventional power. The conclusion reached for Turkey will certainly be applied to most of the under developed countries which do not have as much conventional power resources as Turkey. The similar conclusions were reached by most of the under developed countries as seen in the Second United Nations International Conference on the peaceful use of atomic energy held in Geneva, in 1958.

2 - The cost of Nuclear and Conventional Power

(a) The unit capital cost of nuclear power is larger than that of conventional power at the present time. However, the difference is being reduced constantly as the experience accumulates on the design and the operation of the nuclear power plants. The unit cost will continue to be in favour for conventional fueled power plants for smaller sizes. But, the advances made in the field have already made it possible to consider nuclear power plants of 100 MW ranges as economical competing with the others. The cost of electricity in general varies very widely with the location and the size of the power plants.

1.: Peaceful Uses of Atomic Energy

Volume I, United Nations

Geneva (1958)

The table I shows the summary of the power plant costs averaged for USA.

Table I - Power Plant Costs in the USA²

<u>Type</u>	<u>Range</u>	<u>\$/KW</u>	<u>Mills/KWh</u>
Coal-fired plants	400-600 MW	135	2.8
	100-200 MW	150	3.2
	10-50 MW	165	3.5
	Reserved coal pile	7	0.15
	fuel costs \$6-8 per ton		2.4-3.2
Diesel plant	1 MW	160	3.1
	10 MW	140	3.0
	15 MW	135	2.9
	fuel costs 14 ¢/per gallon		9.0
Hydro-electric	200 MW	115	2.5
	100 MW	120	2.6
	50 MW	125	2.7
	10 MW	170	3.6
	Dam and Site	100-200	2.1-4.3

The figures of table I indicates that if all transmission costs are neglected, then the cost of electricity with coal-fired plants varies from 5.4 mills/KWh to 6.4 mills/KWh, with diesel plants from 11.9 mills/KWh to 12.4 and for hydro power plants from 4.7 mills/KWh to 2.9 mills/KWh. In the latter case, the cost of dam and dam-site effects the net result of the power cost very greatly.

(b) The accumulation of the information about the utilization of nuclear power plants also made it possible to reduce the cost of manufacturing of nuclear power plant equipments. On the other hand, the operational experiences will guide the engineers to reach to an optimum design in plant safety requirements as well as in site selection which seems to be an important item in the capital costs of the plants at the present time.

2.: J. Gueron, J. A. Lane, I. R. Maxwell, J. R. Menlee

The Economics of Nuclear Power, Volume I,
UNESCO (1959)

(c) The fuel cost will play a predominant part in the planning of the nuclear power. Here, if the country possesses the required raw material for nuclear fuel production, it may then be possible that by some bilateral agreement with those countries which process and produce nuclear fuel, the required fuel for power production can be obtained at comparative prices. If, on the other hand, the concerned country does not have any raw material then, the problem reduces to the comparison of the cost of nuclear fuel imported and that of other conventional fuel produced or imported for power production. In any event, if the fuel costs substantially lower than those of conventional fuel, then there will be a justification to consider nuclear power plants.

(d) Operations of the characteristics of the power system such as the load factors also effect the cost of power generation very greatly. J.M.Key³ in his paper showed that the cost of electricity for nuclear power plant at load factors more than 40 per cent would be very much less than the cost of electricity for the coal-fired plants. On the other hand, very high percentage load factors can only be obtained in highly industrilized countries. Thus, it is necessary that, the under developed country must at least have some region highly industrilized in order to justify the use of large base load power plants which could be nuclear type. In reference 3 the cost of nuclear power plants and hydro power plants was given which indicates that only for load factors more than 60% nuclear power may be comperable to hydro power, if it has the large head and much less favourable storage areas. For hydro power plants built on large run of rivers or on site with favorable storage areas, the capital cost are always in favour of hydro-plants when comparing with conventional nuclear plants of the present types in use.

3 - The Effect of the Development Plans

(a) The economic and social forces in the under developed countries are effecting the way of lives of the people of these countries so much that, practically every one of the so called under developed countries are making plans for the redevelopment of their country. The plans produced by the Planning Boards of these countries give very high importance to the development of power systems which will be the first requirements for industrilization. The objectives of such plans are to find the optimum relations between the required total national investment and set goals for the increase of net national income per year. It is

3. J.M.Key, The Role of the Nuclear Energy in Relation of Other Methods of Electricity Generation

possible for the planning experts to draw-up the development programs for all the sectors of economy of the country, by using the following facts:

- (i) the rate of increase of population
- (ii) the pre-development per capita income
- (iii) the required or fixed goal for per capita income
- (iv) assessed information on:
 - a. natural resources
 - b. human resources
 - c. industrial and agricultural resources.

From these fixed objectives for industry and other sector of economy, the development plan will be emerged which will also include the requirements for electrical energy in different periods of the development programs. The power authorities must therefore, in turn, make their own power system development by taking all available resources into consideration. The power authorities should consider all possible sources of energy for power development and they should try to estimate the cost of the power generation⁴ with various resources including the nuclear fuels for an optimum decision.

(b) The energy requirements for the planned industries in the development programs will effect very greatly the policy of utilization of energy resources of the country. The policy for the development of the power system may include nuclear power plants if in addition to the conditions defined in paragraphs 2a-d, other technical aspects such as given below exist.:

- (i) Multi utilization of nuclear fuels by using a breeder power stations, the power output would be increased by a hundred percent. The essence of this system is to use plutonium as fuel for power station which simultaneously thorium would be converted into uranium 233. It is expected that the doubling period for this system can be estimated to be in 5 to 6 years⁵ and such cycles may be repeated. Hence, the cost of conventional fuel power generation would be higher than the generation for breeder power plants.
- (ii) The conventional fuels will load the transportation system so much that, if all the estimated power for the country produced by coal-fired power plants in future, it may require a huge investment for the transportation system which, in turn, increases the cost of energy and manufactured goods.

4. Introduction to the Methods of Estimating Nuclear Power Generating Costs, Technical Report's series, No.5
IAEA, VIENNA (1961)

5. H. J. Bhabha, The Need for Atomic Energy in the Under-Developed Countries, Peaceful Uses of Atomic Energy, Vol.I, UN, Genova (1958)

- (iii) Since most countries including under developed areas have some kind research reactor for research and isotop production purposes where nuclear engineers and scientists will be trained. It is, therefore, possible to use the knowledge and experiences of these trained people. The authorities bound to face the pressure of them for development of nuclear power plants. However weak, this psychological fact should not be underestimated.

4 - Power and Energy for Turkey:

(a) Resources:

Studies made by the Bureau of Electrical Etude Organization(EIEI), and General Directorate of Mining Exploration Organization indicated that, Turkey possesses considerable natural resources for power production. Turkey's known hydro-potential, which can be developed economically, amounts to 25×10^6 kW yielding 90.000×10^6 KWh of electrical energy⁽⁶⁾. Unfortunately, most of these hydro power are located in Eastern Turkey while the industry and large load centers are in western Turkey. Therefore, considerable transmission costs must be contemplated for their utilization. Turkey's coal reserves are divided into two groups:

- (i) High quality black-coal which has a known reservoir of 600×10^6 metric ton⁽⁷⁾, and estimated reservoir of 1332×10^6 metric ton. The requirements of the present and planned heavy industry do not justify to use high quality coal for future power development⁽⁶⁾. Another factor is that, the high quality coal is located around Zonguldak which prohibits its transportation over a long distance.
- (ii) Brown coal:
The known brown-coal reservoirs of Turkey have a capacity of 400×10^6 metric ton. Their use for power production increased since 1955⁽⁸⁾. Unfortunately, they must be used locally where condensation water for power plants seems to be a serious problem.

6. M. N. Parlar, K. Sarioglu, Türkiye ve Atom Enerjisi, Chapter III
T.G.S. ARGE, Ankara (1956)
7. Symposium on Coal
CENTO, Dec. (1961)
8. Türkiye Elektrik Enerjisi İstatistik Bülteni (1959)
EIEI Publication (1960)

(iii) Liquid fuel:

Turkey has a limited petroleum reservoir which cannot be considered for large power production.

(iv) Nuclear fuel:

The explorations made by MTA indicated that, there are, at least, four regions in Turkey which may provide rich raw materials for fuel production. The conclusive results will be obtained after further geological researches in those and other regions in the country.

(b) The past, present and estimated power and energy requirements for Turkey follow an interesting pattern. Table 2 shows the trend in power generation and expected or estimated energy requirements for the years 1940-1975 (7).

Table 2 - Gross Production and Estimated
Production of Electricity for
the years 1940-1975.

UNIT - 10^3 Kwh.

Year	Thermal	Hydro	Total
1940	383.004	13.894	396.898
1945	504.046	23.762	527.808
1950	759.524	30.100	789.624
1955	1.490.668	89.150	1.579.818
1960	1.813.661	1.001.410	2.811.071
1961 M	1.773.500	1.276.500	3.050.000
1965 E	-	-	6.370.000
1970 E	-	-	9.150.000
1975 E	-	-	13.000.000

M= provisional figures, E= estimated figures.

It should be noted that, the estimated energy requirements in table 2 corresponds to a per capita energy of 200 kwh-P/Y, 250 Kwh-P/Y, and 310 Kwh-P/Y for the years 1965, 1970, and 1975 respectively which are less than the figures exist for Bulgaria, Yugoslavia and other European countries reached in 1960.

Table 3 shows the past, present, and estimated required installed capacity in Kws.

Table 3 - Installed and Estimated Capacities
for 1940-1975.

UNITS-in Kw.

Years	Thermal	%	Hydro	%	Total
1940	209.946	96.8	7.016	3.2	216.965
1945	235.962	95.9	9.976	4.1	245.938
1950	389.896	95.6	17.885	4.4	407.781
1955	573.515	93.8	38.118	6.2	611.633
1960	860.528	67.6	411.904	32.4	1,272.432
1961 M	881.200	65.6	462.023	34.4	1,343.223
1965 E	-	-	-	-	1,973.000
1970 E	-	-	-	-	2,740.000
1975 E	-	-	-	-	3,250.000

M= provisional figures, E= estimated figures.

For an under developed country it is not possible to calculate the future capacity and energy requirements by the same methods used for the developed countries. The best, engineers in under developed countries, can do, is to study historically the industrial development of many countries and select the one which shows similarity for their country as a guide. By comparative method one can easily see that the estimated figures in the last two tables are very reasonable. On the basis of Table 3, it is necessary that during the next three-five years interval-Turkey should add 650 MW, 760 MW, and 610 MW capacities to her power system.

(c) Turkey will try to use her enormous hydro-potentials more and more in order to keep pace with the power demand. The details of the new five year development plans submitted to National Assembly is not known yet. But, it is expected that there will be large industrial developments in the Eastern Turkey on the Euphrates and Tigres river basins which will use rich hydro-potentials. However, Istanbul region still will continue to expand her industrial complex, and power demand will increase in accordance with doubling the peak demand on every decade.

5- Conclusion: The trend in the cost of nuclear power will make it more attractive within the next few decades. The operational problems of nuclear power plants are not too prohibitive for lesser developed countries to learn. The training can be done for either if one has to start from beginning.

The power requirements in Turkey and especially in Istanbul region may open a possibility for nuclear power development by 1980, if the load follows the estimated pattern which shows similarity to some European country now are considering nuclear power plants.



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Agenda Item: A.3.2.2

Portugal

FLOODS IN TROPICAL REGIONS

By BETTENCOURT MORENO,
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Floods in tropical regions

by Bettencourt Moreno, Civil Engineer, Overseas Ministry

- 1 - The flow characteristics of the african rivers and especially the flood discharges to choose for the calculation of the several organs of a hydraulic project are greatly important for the economy of the structures to build up.

The elements determined in the Portuguese Guinea and in Angola as well as in other territories of the west tropical Africa, have revealed differences in respect to the temperate regions, better known by the technicians, from that fact resulting the interest in their study and investigation.

- 2 - As well known, the run-off is the consequence of the climatic characteristics, in special those of the rainfall. The investigations being made by the meteorologists in the tropical regions of Africa have shown peculiar patterns.

So, F. Bultot (1) remarks: that the rains in tropical regions have an "organized" character, that results, after all, from an "organization" of the air termic convection; that the rains on every day are generally grouped in a zone of limited extension, named "rainy zone"; that the rains within the "rainy zones" are not similar to the frontal rains, generally continuous in space and time, of the temperate regions, and, on the contrary, the rains fall under the form of showers; that the "rainy zones" are not constantly fed and so, contrarily to the frontal rains, 24 hours and often larger interruptions can be observed between two successive rain periods. The conclusions of the work were studied in Angola, for the heavy rainfalls of April 1954, by Dario Queiroz, from the National Meteorological Service, who concluded that, in a general way, they could be applied to the rains in Angola. The main observed difference was in the displacement movement of the "rainy zones", which in the Ex-belgian Congo is West to East as most frequent direction whereas in Angola seems to be East to West. Other later works can still be referred to, namely those by D.H. Johnson (2)

(3), where it is stated that, in tropical regions, more important than the amount of rainfall is its distribution and that the big rainfalls have a tendency to occur only in limited regions. So, the area of the region, the density and the total amount of rainfall are closely linked.

- 3 - The tropical rainfall characteristics that have been and are being determined, but are not liable to be easily quantified due to the insufficiency of the rainfall measurement stations existing in Africa, explain, in a large part, the peculiarities that have been and are being known in flows of the african rivers.

In fact, though the great rainfall intensities, for periods running from 10 to 120 minutes, that have been calculated for purposes of drainage and sewerage of rain waters in the great towns of the Portuguese Africa, reach the higher values, when compared with identical values obtained in towns from Europe, Canada and United States, - see Fig. 1 -, the flood discharges calculated for some hydraulic projects of the Portuguese Africa, as well as those obtained in some watersheds of the Africa of french and belgian expressions, give low values, in comparison with those normally considered in the temperate regions.

Therefore, in Fig. II, taken from (4), where such discharges are marked, it can be seen that all of them are located below the Greager curve with $C=30$ (curve v_7), which is the lower involving curve of the maximum floods known in the United States and in other countries of the world. Attention must also be drawn over the marked values accompanying the curve H_3 - Dickens' formula, determined for India, country equally located in the tropical zone.

It must be noticed that the marked points respecting to the Portuguese Africa are project values obtained from discharge measurements made in the corresponding rivers, refering, as a general rule, to a small number of years, and from theoretical considerations based on discussible flood frequency criteria or others. The known flood values or those determined from the maximum levels are situated below those points. So, for Cambanbe, (Cuanza river), the flood discharge was fixed in 10 000 m³/sec, though the discharge calculated by means of the maximum known levels does not go above 4 000 m³/sec. That is to say that, regarding the shortness of elements, the criterion used by the designer is the choice of prudent values.

- 4 - The low flood discharge values registered in the tropical regions seem to have the main justification in the characteristics of the great rainfalls of such regions, especially the discontinuities observed in space and time, in opposition to the continuity existing in the frontal rains of the

temperate regions, since that, in such conditions, not all the watershed is contributing for the increase of the maximum flood discharge and the run-off coefficients are low.

Of course, different will be the case when all the watershed is interested in the shower, what may happen in small river basins, of the order of magnitude of some Km², or else in the case when the main direction of the river is coincident with the displacement of the "rainy zones".

- 5 - The climatic characteristics, principally the high temperatures verified on occasion of great rainfalls, are the main factors responsible for the laterisation of the superficial rocks.

The geomorphology of these soils causes the infiltration of water and subsequent underground basins, that, besides decreasing also the maximum flood discharges, regularize the annual flow and produce high summer discharges. These are other peculiar characters of the african rivers flow that it is of interest to know, as long as more economic projects may result from their study - f.i., facilities for annual and inter-annual regulation and permanent or of great constancy discharges of high values.

- 6 - In the West Africa and especially in the rivers running in the Angola plateau, the longitudinal profiles have, as a general rule, the steeper gradients near the coast, and across waterfalls and rapids. In the upstream and downstream part of this zone the rivers deposit a great amount of sediments, carried down mainly by the flood discharges of the smaller tributaries, and it is through such deposits that the lower river bed meanders, over flowing the higher bed in high water periods and there forming lagoons.

From here results a reinforcement of the peculiar flow characters referred to in 5, by means of the constitution of large natural basins that decrease still more the flood peaks.

We think that the weak flood discharges together with the small gradients are the factors responsible for the formation of such morphologic characteristics, since that, by such means, it is not possible to have in the flood period large current speeds able of deepening and straightening the lower river bed.

The examination of the discharge duration curves of the Cuanza river in Cambambe, from which the one corresponding to the hydrological year of 1955/56 is shown in Fig. III, shows that:

- (i) The average annual discharge is nearly equal to the semi-permanent discharges, for a dry season extending for about 5 months.

(11) The ratio between the maximum and minimum discharges is around 10/1, showing therefore characteristics of little torrentiality.

(111) The integral discharge of the dry season reaches about 30% of the integral annual discharge.

All these conclusions confirm the existence of big superficial and underground basins that regularize the flows, absorbing a large part of the rainy season discharges to give them back in the dry season, and are, after all, the result of the climatic conditions existing in the tropical regions.

7 - In conclusion:

- a . The climatic features, in special the type of precipitation, are the main responsible factors for the low flood discharge values occurring in the tropical regions of the West Africa.
- b . It is of interest to intensify the collecting of data and the research about rainfalls and flows since it will derive from that a large benefit for the economy of the hydraulic projects to carry out in the tropical Africa.
- c . It is desirable to try to determine involving curves for the maximum discharge floods obtained in african regions with similar climatic characteristics, an international co-operation in this field being helpful.

*

- (1) - F. Bultot, Sur le caractère organisé de la pluie au Congo Belge, Bruxelles (1952), INEAC.
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- (4) - Aménagement a fins multiples des bassins fluviaux - lère partie - Manuel de mise en valeur des bassins fluviaux, New York (1957), Nations Unies - Commission Économique pour l'Asie et l'Extrême-Orient.

FIG 1
COMPARISON OF RANFALL INTENSITIES
mm/hour

PERIOD (min.)	BEIRA (1)	BEIRA (2)	L. MARQUES (2)	LUANDA (2)	LISBOA (2)	DE BILT (2) c	TORONTO (2) b	NEW ORLEANS (2) a
10	165	157	180	134	79	33	-	173
20	153	136	-	103	58	27	85	135
30	136	120	114	89	45	22	71	114
60	103	89	72	66	30	-	44	79
120	61	55	50	53	20	-	31	53

PERIOD (min.)	PENSACOLA (2) a	HOUSTON (2) a	MOBILE (2) a	PORTLAND (2) a	PHILADELPHIA (2) a	TACOMA (2) a	BALTIMORE (2) a	S FRANCISCO (3) a'
10	178	184	183	58	137	48	160	59
20	147	150	140	41	100	32	114	41
30	109	123	114	32	81	23	96	30
60	90	86	76	19	50	15	56	24
120	64	56	46	12	30	10	47	14

a) Rainfall Intensity - Duration - Frequency Curves, M.S. Department of Commerce, Weather Bureau, Technical Paper n°. 25, Washington, D.C., December 1955

b) J.P. Bruco, Ciro 3030, Meteorological Branch-Department of Transport, Canada.

c) Levert, Rains - A statistical study, Koninklijk Nederlands Meteorologisch Instituut (1954)

d) Arantes e Oliveira, O regime de chuvas em Lisboa. Observatório Infante D. Luis, (1942)

(1) Frequency 1/20
(2) " 1/5
(3) "

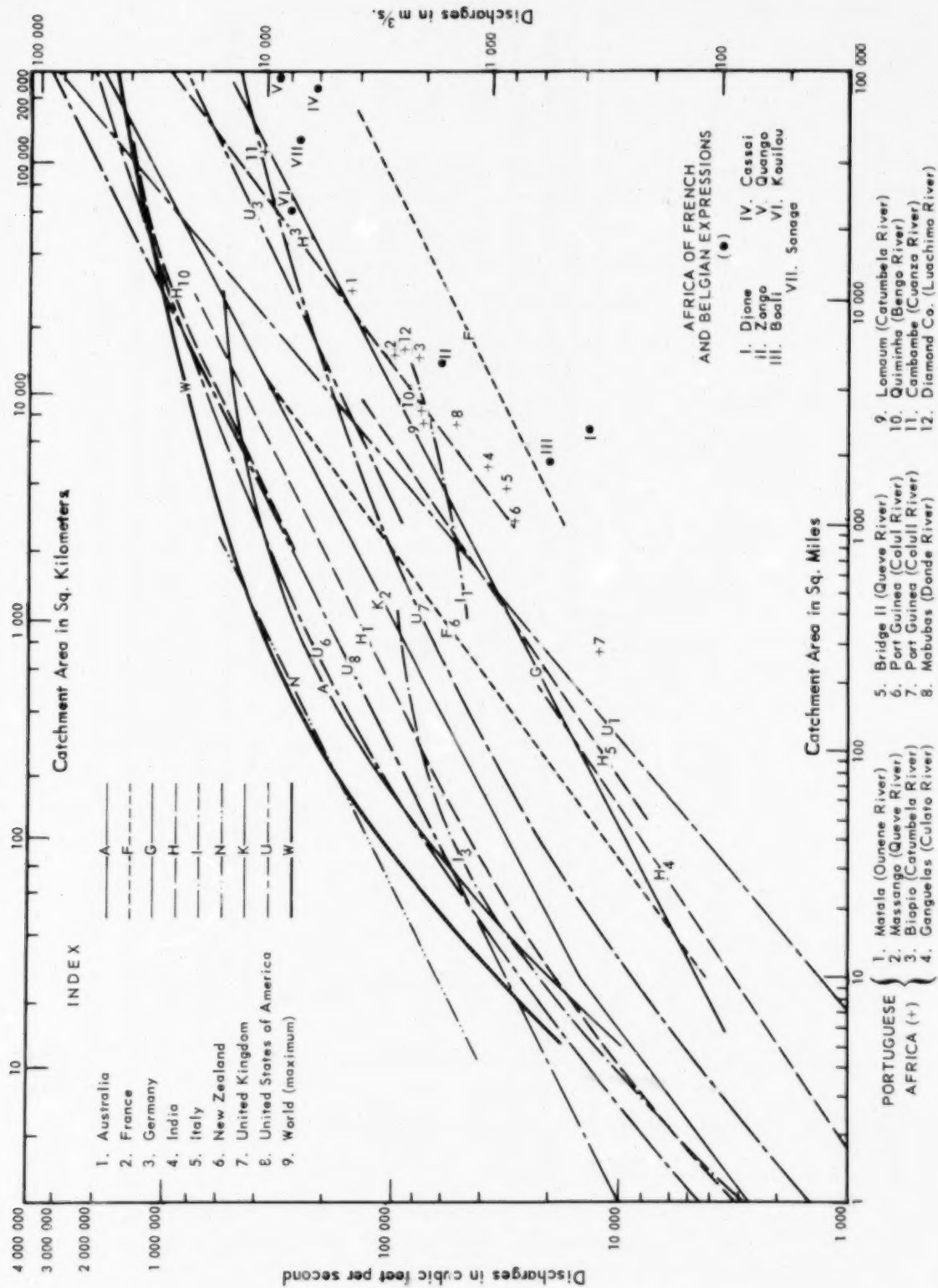


Fig. III — FLOOD DISCHARGES
(Extracted from fig. 5 of publication (4), that compares the formulae generally used to estimate floods)

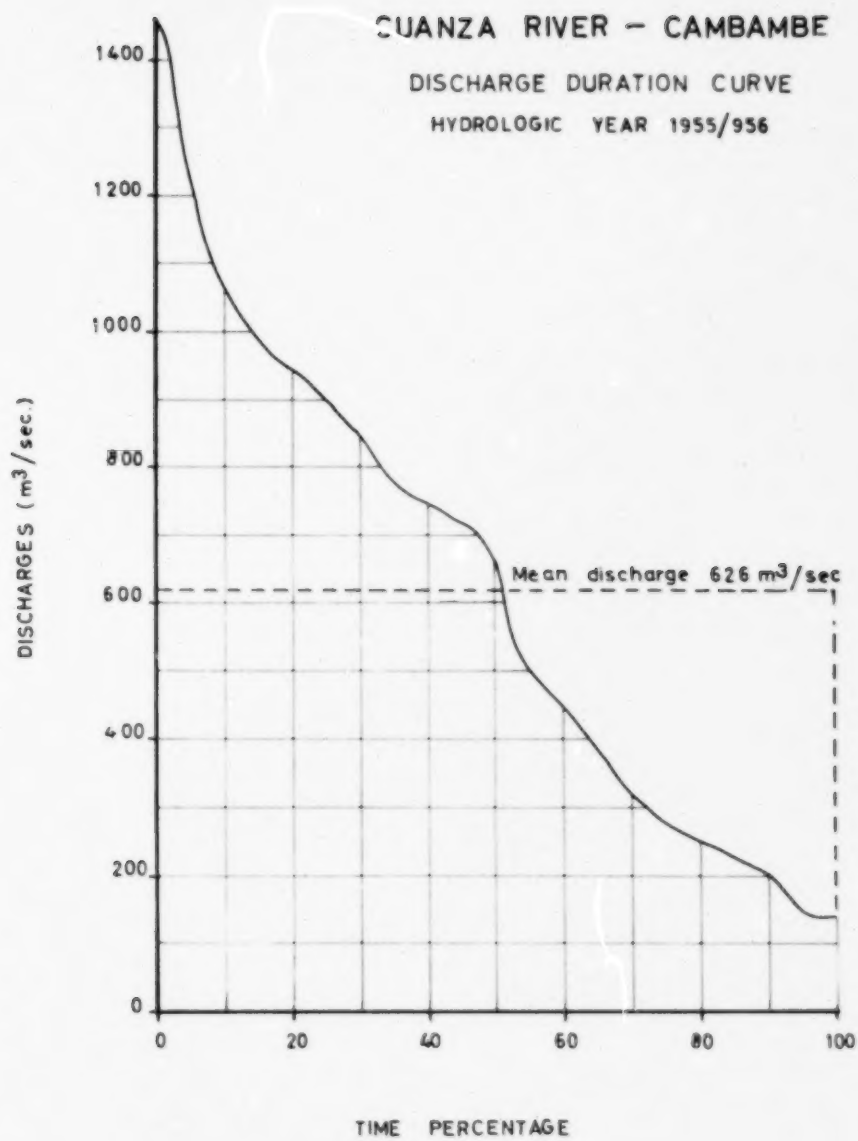


FIG III



UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

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Denmark

THE DANISH WELL RECORD DEPARTMENT
AND THE APPLICATION OF GEOLOGY,
GEOCHEMISTRY AND GEOPHYSICS
IN THE SEARCH FOR GROUND WATER IN DENMARK

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Professor at the Technical University of Copenhagen

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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The Danish Well Record Department and the
Application of Geology, Geochemistry and
Geophysics in the Search for Ground Water
in Denmark

By

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1. HISTORY AND LEGAL ASPECTS

The first drilling campaign for extraction of ground water in Denmark started in about 1870. Favourable drilling results were obtained in numerous cases, and from about 1900 it was quite common to drill water wells over all of Denmark.

It was soon realized that the data on the subsurface formations and their fluids as known from wells could be generalized in larger or minor areas around the wells. Moreover, valuable assistance in the planning of water wells was occasionally obtained by consulting geologists who had certain knowledge of the nature and distribution of the subsurface formations.

As water consumption increased the legal regulation of the exploitation of ground water became necessary. The first Danish Law concerning Water Supply was proclaimed on the 31st of March 1926. Article 1 of this law determines that all wells drilled for water must be reported to the Geological Survey of Denmark. The well reports should include data on the subsurface formations (particularly aquifers), the ground water table, and pumping tests.

This article forms the legal presupposition of the subsequently established Well Record Department of the Geological Survey. The reasons for the inclusion of the article in the law was the experience that many of the water supply problems related with the apparently fortuitous occurrence of aquifers and the variation of the chemical properties of the ground water might be solved by various geological approaches. Similar views underlie the articles on reporting of boring data to the Geological Survey in the "Law concerning prospecting for and production of raw materials in the sub-surface of the Kingdom of Denmark" of the 19th February 1932 (revised 8th May 1950), and in the "Ministry of Justice decree of 13th August 1939 concerning the drilling of gas wells".

The Well Record Department of the Geological Survey became the depository of all reports on borings, and it accordingly developed into a real subsurface department where all important information on the subsurface and its fluids were filed.

The following brief outline of the geohydrology of Denmark will show some of the problems involved in water supply based on ground water in a humid area. The role of the Well Record Department in the solution of these problems is subsequently sketched.

2. GENERAL HYDROLOGICAL PROBLEMS OF DENMARK

The European part of the Kingdom of Denmark covers an area of 43,042 km² with a population of 4.5 millions. The land area consists of the peninsula of Jutland and a number of larger and smaller islands. The rivers are generally small, and practically all water supply is based on ground water. The average water consumption is about 270 l/day/person.

The production of ground water is based on various types of aquifers of which the most important ones are:

- a) the White Chalk and the Danian limestone of the upper Cretaceous system,
- b) the Greensand limestone of the basal Tertiary,
- c) the quartz sands and gravels of the Miocene, and
- d) meltwater sands and gravels in the Pleistocene glacial drift.

Practically the entire country is covered with glacial drift, which mainly consists of boulder clay in about one third of the area. This part of the country is inhabited by about one third of the population, and several important cities with industries dependant on water supply are situated in this region. Meltwater sands and gravels occur at random in the boulder clay areas.

The regional dip of the formations at the base of the glacial drift is mainly W and SW. This implies that e.g. the White Chalk and the Danian limestone successively occur at greater depths in going from E to W. These aquifers therefore enter deeper ground water zones, where ascending brines from pre-Cretaceous saltbearing formations or connate water occur. It is accordingly impossible to produce freshwater from the Chalk and the Danian limestone in the main part of Jutland and in several other areas. The Miocene quartz sands and gravels occur in Central Jutland and parts of South Jutland. They may thus to a certain extent act as a replacement of the useless saltwater bearing Chalk and limestone at greater depth.

Apart from the salt water at depth there are several shallow occurrences of salt connate water in marine Pleistocene deposits embedded in the glacial drift, and sea water may infiltrate the aquifers in coastal areas. There are accordingly several hydrological provinces in Denmark, each with its own features.

In summarizing the water supply situation of Denmark we may state the following main problems:

- a) Estimate of depth to potential aquifers.
- b) Location of irregularly distributed sand and gravel beds in the glacial drift.

- c) Estimate of depth to ground water table.
- d) Location of salt water occurrences.
- e) Evaluation of aquifers.

3. ORGANIZATION OF THE WELL RECORD DEPARTMENT

(a) File of Well Logs.

Graphic logs are traced on the basis of the drilling reports submitted by the well drillers. Many drillers forward samples of the penetrated formations, which are examined by the geological staff of the department and classified in accordance with their lithology, fossil content etc. The drilled sequence is thereafter subdivided stratigraphically in a more or less preliminary way. The waterbearing horizons, water levels and pumping tests are also indicated on the log.

Reference is furthermore made to water analyses if present, and to any special investigations of formations, water properties etc.

The well location is finally plotted on a map to the scale of 1:40,000; 1:20,000 or (in cities) to a larger scale. The well log is furnished with the number of the map and a serial number, which is written at the well location on the map, whereby the log is ready for filing. The logs are filed in accordance with the number system of the maps.

The file of graphic well logs and the location maps form the backbone of the department. By means of this material it is possible to utilize the data available with a minimum waste of time. If information on a certain area is wanted, the map concerned is consulted for well logs on file, the volume with the logs is taken out of the file, and compilation of pertinent information for the special purpose may be started immediately. It is obvious that the density of wells is different in the different areas, and that information was very scanty in many areas, especially in the beginning of the existence of the department. However, even a single well log in an area is extremely useful for a trained geo-hydrologist in estimating ground water conditions.

(b) File of Water Analysis.

The following ions are generally determined in water analysis in Denmark: HCO_3^- , SO_4^{--} , Cl^- , NO_3^- , NO_2^- , PO_4^{--} , Ca^{++} , Mg^{++} , Fe^{++} , Mn^{++} , NH_4^+ and Na^+ ($^+\text{K}^+$). Furthermore Oxygen consumption, SiO_2 , pH, free CO_2 and hardness degrees are determined. Values are given in milli-equivalents.

The geochemical laboratory of the Geological Survey does some analytical work and collects copies of analyses carried out by commercial laboratories for well owners. All analyses are written on a standard scheme which also includes a graphic column showing the ion content in the water. The analysis cards are filed in the same number system as the well logs and are accordingly as easy available as the logs.

(c) Collection of drilling samples.

Since the final goal of the Department must be the compilation of various sorts of subsurface and hydrological maps, a scientific treatment of the material had to be foreseen from the start of the department.

It is in general impossible to solve all scientific problems during the current daily work which is more or less of a routine nature. A number of studies have, moreover, to be postponed due to lack of sufficient information.

Under these conditions it rather soon proved imperative to build up a collection of formation samples from the drillings for future studies and for reference purposes. The most important samples are therefore kept in storehouses from where they may easily be delivered to the laboratory on short notice.

(d) Water table gauging stations.

The increasing water consumption of the growing cities and industries have resulted in a lowering of the water table and inconveniences for other consumers in many regions. This development has of course important legal aspects, and the need of an objective determination of the variation of the ground water table was accordingly obvious rather early. In 1950 the Geological Survey started observations on the "natural" variation of the water table in about 80 wells in all parts of the country. These wells are preferably located outside the influence of the big water supplies. The gauging is carried out by local laymen, and continuous hydrographic recorders are installed in a few wells.

(e) Geoelectric Resistivity Surveys.

The steady increase of water consumption implied that methods of rational prospecting for aquifers and for the proper location of drillings became more and more desirable. In 1953 geoelectric mapping by means of resistivity measurements were therefore developed with special regard to the geohydrological conditions in Denmark. Geoelectric surveys have since then been carried out in all parts of the country. Three field parties are now at disposal for this kind of work.

4. CONSULTING ACTIVITY AND GROUND WATER PROSPECTING

Immediately from its start in 1926 the department acted as an adviser of water well drillers and water supply engineers in geohydrological matters. At the beginning the department served as an information centre from where the drillers and engineers could obtain more general information on the occurrence of potential aquifers and the over all quality of the ground water in a given region. Landowners and citizenships also often requested the assistance of the department. In practice the advice was either given by correspondence during personal application to the department, or by telephone.

Later, as the amount of data accumulated and the accuracy of forecasts improved for various regions, it became more and more common for well drillers

to ask for drilling programmes. Besides many well drillers currently consulted the department while drilling a well in less known regions regarding the chances of encountering aquifers. Samples of the formations were forwarded at intervals or daily, and after examining the samples the department informed the driller by correspondence or by telephone of the prospects. This service has been utilized rather intensively, and a number of big drilling firms have for years based their bids and work on drilling programmes and forecasts obtained from the Well Record Department of the Geological Survey.

As time went on and the amount of data and the staff of the department increased, it became possible to undertake larger enterprises. Major reports on geohydrological conditions of special regions were prepared as part of regional water supply planning. This work often included extensive field work, compilation of well data and water analyses, and study of the files of cities and industries.

The latest technical improvement of the department was achieved by the establishment of the gauging stations in 1950 and the organization of the geoelectrical section in 1953. The department has since then been fully equipped for rational ground water prospecting under the special geohydrological conditions prevailing in Denmark.

At present a general prospecting programme as carried out for rural or municipal water supplies, industries, and landowners includes the following works:

- a) Compilation of geological and hydrological data from the files of the department and from literature for a brief outline of the geohydrology of the area.
- b) Planning of a geoelectrical survey if it is impossible to indicate suitable drilling locations on the basis of pure geological evidence.
- c) Geoelectrical field work.
- d) Preparation of geoelectrical report with recommendations for drilling.
- e) Drilling of wells..

The geoelectrical surveys are generally carried out in accordance with the WENNER Method. "Trenching" measurements by which the horizontal variation of resistivity is measured to a constant depth are combined with "vertical" measurements by which the vertical variation of resistivity is determined at selected stations. The results are finally interpreted geologically.

The following three case histories from the start of geoelectric surveys in Denmark show the applicability of the working procedure. More than 100 surveys have since then been carried out. All sorts of projects have been dealt with, including mapping of different formations, structures and salt water occurrences, and determination of depths to formation boundaries, the ground water table and freshwater - salt water contacts.

5. CASE HISTORIES

(a) Landet, island of Taasinge (Rural water supply).

Inhabitants of three villages on Taasinge decided to establish a co-operative waterworks at Landet in 1953. The engineer in charge of the estab-

lishment accordingly enquired the Well Record Department of the Geological Survey regarding a drilling location. It was recommended to drill at a suitable place on low elevation in the valley in which the villages are situated, and which crosses the island from SE to NW.

The valley is assumed to have originated as a subglacial tunnel valley during the last glaciation, and it might, therefore, be suggested that gravel and sand should be present somewhere in the subsurface Pleistocene deposits of the valley. It was the scope to locate such permeable beds which might act as aquifers. The proposed drilling programme included drilling to be discontinued as soon as Tertiary clays were encountered. Further drilling would thence be useless due to the absence of aquifers in the Tertiary beds and the presence of salt water in the Danian limestone below.

Three wells were drilled in different places but they proved all dry, and in each case they displayed practically the same sequence: a series of Boulder clays resting on sticky Lillebelt clay or Røsnes clay of the Eocene. The Eocene beds were encountered at about 40 m below surface.

The subsequently planned resistivity survey included vertical measurements at each of the dry holes and a resistivity mapping ("trenching") of the glacial drift using an electrode spacing of 50 m and covering about 1 1/2 square kilometres of the valley bottom.

Very low resistivity values were obtained in the area, and it was obvious from the resistivity curves that the Tertiary Lillebelt and Røsnes clays had very low resistivities.

The iso-ohm map displayed two maximum anomalies, one over elevated ground on the northern slope of the valley with the highest resistivity values, and another one on the bottom of the valley N of Landet church. The last-named was interpreted as suggestive of gravel and sand accumulations in the glacial drift. The possibility of the high resistivity being indicative of partly dry beds above the groundwater table could be disregarded since the valley is very level over the area concerned, and the groundwater table could be assumed to be very near the surface. It was finally recommended to drill a well in the center of this anomaly.

A shallow sand and gravel deposit was encountered under 1 m of soil and clay, and a screen was set in relatively coarse sand and gravel from 18.4 to 25.4 m below surface. The water table was at the surface, and the yield of the well was 10 cubic m/h at a draw down of 3 m.

(b) Marslev Dairy (Local water supply).

The dairy needed more water for the manufacturing of milk products than its wells could produce in 1953. A new well did not succeed in finding water-bearing beds in the Pleistocene, which was penetrated at 35 m and underlain by Paleocene clays. Moreover, the Paleocene beds proved to be salt water bearing from a depth of 46 m. After this failure the proprietor requested the Geological Survey to make a resistivity survey of an area near the dairy.

The area concerned was covered with 50 m trenchings in order to register the drift resistivities. A broad maximum which extended toward the dairy was defined south of the dairy. Drillings were recommended at an extension of the

maximum near the dairy. Four wells were drilled. Each of the wells proved the presence of sand and gravel beds and the capacities of wells no. 1, 3 and 4 were from 21 to 24 m³/h at 3.5 m depression of the water table. The log of well no. 1 was as follows:

File no. 146.197.a. Marslev Dairy.

0-11.5 m Fine melt-water sand, argillaceous
 11.5-14.5 m Melt-water clay
 14.5-16.5 m Melt-water sand and gravel, waterbearing
 16.5-17.0 m Boulder clay, not penetrated.
 Water table 1.5 m below surface.

(c) Rislev. (Salt water occurrence).

HEE ANDERSEN and ODUM mapped an inland occurrence of salt marsh plants in the bog Slagmose at Rislev in 1923. Subsequently drilled wells encountered shallow Bryozoa limestone at about 8 m depth with salt water of 1.033% NaCl in the center of the bog.

The bog was made the object of a resistivity survey in 1953 which aimed at investigating the salt water occurrence. Trenchings with a-25 m a-50 m and some vertical measurements were planned. During the course of the survey it turned however out to be impossible to obtain readings with an electrode spacing of 50 m, and it was, therefore, necessary to confine the study to a 25 m mapping and a single vertical measurement.

The iso-ohm map showed a very simple pattern with the lowermost resistivity found in the center of the bog being the center also of the area of the salt marsh plants as outlined by HEE ANDERSEN and ODUM in 1923. The resistivity minimum may mainly be related to the salt water which ascends from the deep subsurface to the surface of the bog. The salt water may thus be the overwhelming factor affecting apparent resistivity in the area according to this interpretation.

The iso-ohm contours were almost conformable with the contours of the surface topography around the bog basin, which might be indicative of continuous increase of hydrostatic deficit in the low lying area of the bog from the margin of the basin to its center, due to natural drainage of the ground water and corresponding increase of elevation of the salt water in the subsurface.

6. DEVELOPMENT OF STAFF AND ACTIVITY

A very brief statement regarding the staff and growth of the department might be of interest in the present connection.

<u>Development of staff</u>	1926	1934	1942	1950	1961
Geologists	1	2	3	6	11
Chemists	1	2	2	2	4
Geophysicists					2
Assistants				1	3
Draftsmen					3
Office personnel				1	4
	<u>2</u>	<u>4</u>	<u>5</u>	<u>10</u>	<u>27</u>
	----	----	----	----	----

Consulting, reports on wells, samples and geoelectric surveys.

	1926	1934	1942	1950	1961
Consultings	30	202	166	503	914
Reported wells	379	826	1535	2213	2460
Rock samples	x)	x)	x)	12644	14325
Geoelectric surveys	+	+	+	+	23

x) not recorded

It has been a leading principle to publish papers on special subjects as: subsurface geology, hydrology, geochemistry of ground water, geophysics, structure etc. at intervals. The basic idea is that consulting activity has to be followed up by research in order to improve the service to the public. The work of the staff may accordingly be subdivided in the following three main categories:

- a) Routine work
- b) Consulting
- c) Scientific research.

Each of these categories covers about one third of the working capacity of the department.

It should be added that the department now deals with practically all subsurface matters including hydrology, mineral deposits, hydrocarbons etc. Geohydrology is however still the most important part of its work.

7. APPLICABILITY TO OTHER AREAS

The intention with this brief outline of the history and activity of the Well Record Department of the Geological Survey of Denmark has been to show that a general file on subsurface geology and hydrology is the basic presupposition of rational ground water prospecting.

The geohydrological conditions may change from place to place. There is, however, no doubt regarding the adequate approach to their solution. The ground water problems must be treated with geological methods in which geochemistry and geophysics have to be included as aiding tools.

The developments in Denmark have proved that even a small staff of well experienced geologists and chemists may contribute considerably to the solution of regional and local ground water problems if they systematically accumulate data from wells from the beginning. It is, however, very important to keep in mind, that each region has its particular problems, which need scientific consideration and research in a major or minor degree. Current research is therefore absolutely necessary.

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CONSIDERACIONES SOBRE LOS METODOS
Y RESULTADOS OBTENIDOS
EN LA PROSPECCION DE MINERALES RADIATIVOS
EN ESPAÑA

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CONSIDERACIONES SOBRE LOS METODOS Y RESULTADOS OBTENIDOS

EN LA PROSPECCION DE MINERALES RADIATIVOS EN ESPAÑA

por Manuel Alía.- Catedrático de Universidad. Jefe del Servicio de Investigación Geológica de la Junta de Energía Nuclear. Madrid. España.

1.- Los yacimientos de minerales radiactivos con interés económico, hasta ahora localizados en España, corresponden principalmente a formas filonianas intragraníticas, a impregnaciones en pizarras próximas a los granitos, o a formaciones de metasomatismo entre granito-calizas. Los materiales en que aunan dichas mineralizaciones son de edad paleozoica, afectados por la orogenia hercínica. Por el contrario, no se han encontrado verdaderos yacimientos de tipo sedimentario, pues las mineralizaciones radiactivas que se localizaron en sedimentos más modernos y que pueden referirse a este tipo son, en general, muy reducidas y otras no son por ahora económicamente beneficiables (caso de las mineralizaciones en el Ordoviciense de Despeñaperros). Esta especial tipología de los yacimientos radiactivos de interés, con mineralizaciones limitadas y normalmente de poca extensión superficial, obliga a utilizar mallas apretadas de prospección y no permite el empleo de los métodos de reconocimiento de gran radio, si no es para los primeros trabajos de orientación.

2.- A esta dificultad de la prospección de los radiactivos en España se añaden otros inconvenientes, derivados de la complejidad geológica y estructural, la accidentación topográfica y las condiciones climáticas de muchas regiones.

3.- La mayor extensión del territorio español está constituida por un complejo mosaico de terrenos de diversas edades y naturaleza geológica que, por lo general, han sido intensamente afectados por el diastrofismo cortical. En estas circunstancias, es difícil establecer normas geológicas generales que puedan hacerse válidas para la prospección de amplias zonas. Unicamente las extensas cuencas interiores, con rellenos de sedimentos del Terciario, presentan una constitución geológica más sencilla y homogénea pero, en tales sedimentos, las posibilidades de existencias de radiactivos son escasas.

4.- La accidentación topográfica es también un factor que debe tenerse muy en cuenta. Gran parte del territorio español corresponde a terreno montañoso y a veces, a montañas y cordilleras, cuyas cimas más destacadas llegan a elevarse por encima de los 3.000 m. de altitud. En consecuencia y en especial en las zonas de mayor relieve, las vías de penetración son lógicamente más limitadas y ello contribuye, junto con su misma accidentación, a hacer más difícil la prospección en tales lugares. Las superficies de llanuras se desarrollan principalmente en las formaciones sedimentarias prácticamente estériles del Terciario, acabadas de mencionar y

también, como penillanuras de arrasamiento, en algunas áreas constituidas por materiales más antiguos. En estas últimas, es frecuente que la red hidrográfica actual se encuentre muy encajada, lo cual motiva un mayor descenso del nivel freático de las aguas profundas marginales, las cuales, ya de por sí, se presentan rebajadas, como consecuencia de las condiciones de semiaridez climática de muchas regiones. Estas circunstancias que también se producen en áreas montañosas, pueden motivar la destrucción parcial o total de las mineralizaciones radiactivas existentes, especialmente de las secundarias de alteración, por lixiviación ocasionada por el drenaje profundo marginal. Por este proceso, a veces quedan mineralizaciones "colgadas" (1), las cuales son difíciles de interpretar por lo que se refiere a su significado y posible continuación en profundidad.

5.- En la mayor extensión del territorio español, con excepción de las zonas montañosas, especialmente las septentrionales, la media pluviométrica anual es escasa y los veranos son particularmente secos y con elevadas temperaturas. Estas circunstancias climáticas son favorables por lo que a los reconocimientos geológicos se refiere, por tanto que impiden, en general, el desarrollo de cubiertas vegetales tupidas. Pero, al mismo tiempo, constituyen un inconveniente para la prospección de radiactivos ya que dichas condiciones de semiaridez motivan el rebajamiento del nivel freático de las aguas profundas y, por consiguiente, el desarrollo de amplias zonas de alteración. En estas zonas, los minerales secundarios de uranio, fácilmente lixiviables, pueden ser removilizados y dispersados por los variados procesos que en ellas concurren, con lo cual pueden originarse localmente concentraciones radiactivas derivadas, y también, pueden producirse modificaciones importantes en las zonas de alteración de los yacimientos originales, en las que a veces se forman así niveles estériles intercalados. Todo ello puede conducir a la incertidumbre en la valoración y significado de los hallazgos hechos en la superficie y a la necesidad, muchas veces, de investigaciones complementarias mediante trabajos de profundidad.

6.- Teniendo presente estos diversos factores, el Servicio de Investigación Geológica de la Junta de Energía Nuclear española, ha aplicado los diferentes métodos usuales de la prospección, adaptándolos en cada caso a las diversas circunstancias concurrentes. Estos métodos utilizados son los que se indican a continuación.

a) Métodos de prospección.

1) Investigación y cartografía geológica.

7.- Todos los métodos de prospección empleados se complementan con trabajos de investigación y cartografía geológica, de distintos grados y escalas, según los diversos objetivos y problemas planteados. En síntesis, estos trabajos pueden referirse a dos grandes grupos: los de carácter regional y los de detalle. Los primeros se realizan como fase previa orientadora, para seleccionar, dentro de cada región, las áreas que por sus características geológico-estructurales, pueden considerarse como más favorables para la existencia de radiactivos. Se efectúan sobre la base del estudio previo de los antecedentes geológicos y mineros existentes, seguidos por reconocimientos en el terreno que realizan geólogos experi-

(1) ALIA, M.- "Relaciones entre mineralizaciones uraníferas en España y la evolución morfológica".- XXI Congreso Geológico Internacional, Sección 15, pp. 67-72.- Copenhague (1.960)

mentados y, a ser posible, conocedores del ambiente geológico regional. En este primer grupo pueden incluirse también, los estudios de síntesis que se hacen al final, o cuando ya está en fase avanzada de prospección e investigación de detalle de una región. Con estos estudios se pretende coordinar los resultados obtenidos para, intentar establecer las relaciones existentes entre las unidades geológicas y las mineralizaciones radiactivas y así poder fijar normas que puedan ser utilizadas en otras regiones de análogas características, o para complementar y detallar la prospección en la misma región de la que se obtuvieron. En este sentido se tiende actualmente a intensificar los estudios genético-estructurales, con objeto de fijar la zonalidad del complejo orógeno herciniano español y de las metalizaciones correspondientes. (2).

8.- Los estudios de detalle comprenden también diversas escalas de trabajo y cartografía geológica. Para la prospección por zonas, se utiliza más frecuentemente la escala 1/50.000, con levantamiento de planos geológico-tectónicos más o menos completos, según las necesidades y la cartografía geológica que exista anteriormente. En las áreas de mayor interés se hacen levantamientos geológicos a escala 1/10.000 y 1/5.000, utilizando para ello ampliaciones de fotografías aéreas. En los trabajos de mayor detalle, correspondientes a los diversos de investigación en afloramientos radiactivos localizados, se acude a levantamientos en escala hasta 1/500. En todos los casos constituye una valiosa ayuda la fotogeología.

ii) Fotogeología.

9.- En fotogeología se trabaja ordinariamente sobre fotografías aéreas con visión estereoscópica y en blanco y negro, a escala aproximada 1/40.000. Para algunos estudios de mayor detalle, se utilizan fotografías a escala aproximada 1/30.000. En el paso de los datos obtenidos en los "strips" a los planos topográficos 1/50.000, no se hace la rectificación ("redressement"), por considerar que el coste de este procedimiento y el tiempo que se invierte en su aplicación, no están justificados con el grado de precisión que se requiere. En su lugar, se sigue el siguiente método: - en los "strips" y al mismo tiempo que el fotogeólogo señala los datos geológicos y estructurales, marca también los principales accidentes geográficos, principalmente ríos y arroyos, para que puedan servir después de referencia en el plano topográfico. Un dibujante especializado, con la ayuda de esta red de referencia geográfica, pasa finalmente y a mano alzada, la información geológica obtenida sobre el plano 1/50.000. La exactitud que se consigue con esta simplificación del método, es suficiente para los trabajos que se han de realizar, sobre todo si se tiene en cuenta, que los geólogos de campo han de comprobar y complementar después la información fotogeológica sobre el terreno.

10.- La ausencia de cubiertas vegetales compacta, facilita la aplicación del método fotogeológico, por el cual se vienen obteniendo buenos resultados. Por la preferente localización de las mineralizaciones radiactivas en los terrenos paleozoicos y por el fuerte diastrofismo que generalmente ha afectado a estos materiales, las interpretaciones presentan con frecuencia dificultades pero, en todos los casos, se consigue una buena información geológica previa, en especial por lo que a alineaciones tectónicas y conjuntos estructurales se refiere.

(2) ALIA, M.- "Relaciones genético-estructurales de algunos tipos de mineralizaciones uraníferas españolas".- Junta de Energía Nuclear. 101-SIG/I 1 pp. 15 - Madrid (1.962)

iii) Prospección radiométrica.

11.- La prospección radiométrica aérea no ha sido utilizada, -- pues se ha considerado que, por la limitada extensión superficial que en general presentan los yacimientos radiactivos hasta ahora conocidos y por la misma accidentación topográfica de muchas regiones, los resultados que se obtuvieran no compensarían el coste de este tipo de prospección, sobre todo si se tiene en cuenta, los trabajos de verificación y relleno radiométrico que después sería necesario realizar sobre el terreno.

12.- Se efectúa la prospección autoportada, con la que se localizan ya algunas mineralizaciones radiactivas. Sin embargo, este tipo de prospección es poco adecuada para muchas áreas, pues por la accidentación topográfica y en consecuencia, la escasez de vías de penetración, las mallas de reconocimiento que pueden conseguirse son excesivamente amplias. En estos casos, no puede concederse demasiado valor a los resultados, cuando éstos son negativos y solo los circunstanciales positivos pueden servir de puntos de partida para los ulteriores trabajos. En lugar de automóviles se utilizan a veces motocicletas, por la mayor movilidad que éstas tienen.

13.- La prospección radiométrica pie a tierra, se efectúa con -- escintilómetros y siguiendo la sistemática usual, desde los simples itinerarios de reconocimiento hasta las mallas de prospección más densas, cuando éstas se hacen precisas. En los terrenos de pizarras, donde las anomalías radiométricas positivas, por la absorción y dispersión que se produce en este tipo de materiales, son menos acusadas que, por ejemplo, en las áreas graníticas, se fija más bajo el "umbral de posible interés" en las mediciones radiométricas y se opera con escintilómetros de mayor sensibilidad posible. Los levantamientos de planos radiométricos se efectúan cuando los afloramientos no están bien definidos en superficie, pero se prescinde de ellos o se simplifican, cuando las estructuras mineralizadas están bien definidas.

iiii) Prospección Geoquímica.

14.- Las características topográficas y climáticas dificultan la aplicación de los métodos geoquímicos clásicos en muchas zonas. Los materiales recogidos para la prospección geoquímica, que dirige F. de Pedro, han sido aguas, aluviones, suelos, rocas y plantas. Los más demostrativos parecen ser las aguas, al considerar en ellas la relación existente entre el contenido de uranio disuelto y la conductividad total, pero está limitado su empleo por razones climatológicas, que obligan a hacer las tomas durante el otoño, en mallas no siempre completas, las cuales se complementan, en lo posible, con la de las aguas de los pozos existentes,

15.- Los aluviones son de utilización más fácil por su persistencia y por la posibilidad de que su fase más arcillosa, represente la media de la cuenca a la que pertenece. En la prospección general de terrenos accidentados, la toma de aluviones a lo largo de los valles puede hacerse con relativa facilidad. Se determinan en estos aluviones los contenidos de una serie de elementos de comportamiento bien conocido (Be, Co, Cu, Mn, Mo, Nb, Ni, Pb, U, Zn y Zr), para definir las condiciones geoquímicas reinantes y después se valora comparativamente el contenido de uranio, con el que debiera haber en el caso de dispersión de un yacimiento. Se supe-- ra así la interpretación que pudiera obtenerse de la única consideración de los valores altos en uranio.

16.- En la fase de prospección regional, se recoge la mayor cantidad posible de muestras de aguas y en los aluviones solamente se analiza el uranio.

17.- La prospección, detallada, en los alrededores de puntos conocidos e interesantes, se hace con malla de 10 x 10 m. analizándose el uranio en muestras de suelos. Cuando el detalle de la prospección lo requiere, se toman muestras tridimensionales, tanto de suelos como de rocas, para así poder levantar planos superponibles, correspondientes a distintos niveles, al objeto de establecer la forma y posición en profundidad de las anomalías. En estos trabajos, la mayor dificultad se encuentra generalmente al tratar de hacer los pequeños sondeos con barrenas de mano, por la compactación y sequedad del terreno y por ello que, en bastantes ocasiones, se tenga que recurrir al empleo de pequeños martillos neumáticos de perforación.

18.- No se ha encontrado ninguna planta indicadora de las mineralizaciones uraníferas, pero se han desarrollado las técnicas de determinación en algunas que son acumulativas de este elemento. De las múltiples plantas ensayadas, la que ha dado mejores resultados ha sido la encina (*Quercus ilex*.) árbol que está ampliamente repartido en muchas regiones españolas y que además, presenta las ventajas de tener hojas perennes y situadas a relativamente poca altura del suelo. En las cenizas de sus hojas, cuando están en terrenos graníticos, la media del contenido en uranio es de 3 ppm., pudiendo elevarse hasta más de 100 ppm. cuando están sobre filón mineralizado. En los terrenos pizarrosos la media baja a 1 ppm. y sobre las mineralizaciones llega a 20 ppm.

19.- La preferencia que el uranio tiene para concentrarse en las lipoproteínas de las aceitunas, según demostraron J.M. Martínez Moreno y all. (3), ha permitido, por nuestra parte, la iniciación de un nuevo método de prospección geoquímica, basado en el análisis del contenido de uranio en los frutos del olivo, árbol muy abundante en gran parte del territorio español.

20.- La interpretación de los resultados obtenidos en los diferentes métodos geoquímicos acabados de indicar, se hace por estadística semicuantitativa, empleando fichas perforadas, para así facilitar el manejo y comparación de los miles de datos analíticos y de observación sobre el terreno.

iiii) Prospección geofísica.

21.- En España solamente se han utilizado hasta ahora los métodos eléctricos, preferentemente el de resistividades. La aplicación de este método se ha hecho fundamentalmente en terrenos graníticos, para la determinación de estructuras de detalle, una vez que han sido localizadas las mineralizaciones radiactivas en superficie. El especialista en estos métodos geofísicos, F. Zuriaga, utiliza el dispositivo simétrico del cuadrípolo Schlumberger, obteniendo muy buenos resultados con distancias de 65 m. para los electrodos AB y de 5 m. para los MN. En las estructuras de potencia reducida, ha sido necesario aplicar los cuadrípolos - AB = 45 m., MN = 3 m. y AB = 22, MN = 2 m. La tensión aplicada generalmente a los electrodos AB durante la mayor parte del año es la de 600 V. En

(3) MARTINEZ MORENO J.M., BERJUDEZ CARACHO E., GOMEZ HERRERA C., JANER DEL VALLE C. - "Prospección de uranio mediante el análisis de las aguas residuales de las almazaras".- Rev. Energía Nuclear. Año VI, nº 22. Madrid (1.962)

la época estival se encuentran grandes dificultades, por ser entonces - muy elevada la resistencia de contacto de los electrodos con tierra. Aunque se ha tratado de superar este inconveniente, regando con agua saturada de sal común y colocando más de un electrodo; prácticamente se ha desistido de la utilización del método durante dicha época del año. Con este método se han obtenido muy buenos resultados en los terrenos graníticos y se han podido así cartografiar estructuras de detalle, relacionadas con las mineralizaciones, sobre planos E=1/1.000. En los terrenos pizarrosos todavía se ha hecho poca labor pero, en lo hasta ahora realizado, se han encontrado mayores dificultades y menos contratos que en los graníticos.

22.- El método de resistividades llamado "Método de los rectángulos" que, como norma general, se utiliza en los terrenos con recubrimiento o con capas superficiales muy conductoras, no ha tenido gran aplicación en España, por la falta o escasez de recubrimientos que en general presentan los terrenos graníticos.

b) Coordinación de los métodos de prospección y resultados.

23.- Como es normal, en la aplicación y coordinación de los diferentes métodos de prospección acabados de mencionar, se sigue la sistemática de las aproximaciones sucesivas y así se empieza con las fases más generales y se termina con las de mayor detalle. En síntesis, las fases y métodos que se siguen para la prospección sistemática de radiactivos, son las siguientes:

i) Prospección General.

24.- Estudio previo de antecedentes y reconocimientos geológicos. P. autoportada. P. geoquímica general.

ii) Prospección Regional.

25.- Sobre planos E=1/50.000. Fotogeología. Reconocimientos geológicos para establecer las mailas de prospección. P. radiométrica pie a tierra. P. geoquímica regional.

iii) Prospección Detallada.

26.- Levantamiento de planos geológico-estructurales de detalle. Planos radiométricos y calicatas. P. geoquímica detallada. P. geofísica. Sondeos.

27.- La aplicación de este plan de trabajos no se hace de una manera rígida y mecánica sino que, por el contrario, en cada caso se hace un estudio discriminativo de las diferentes circunstancias concurrentes. De estos estudios se deduce, frecuentemente, la posibilidad de suprimir fases de prospección intermedias, o de aplicar simultáneamente varios métodos, con lo cual se obtiene una mayor economía en los costes, sin detrimento de la exactitud en los trabajos.

28.- Los resultados obtenidos hasta ahora con al aplicación de estas normas de prospección, pueden considerarse como satisfactorios y alentadores puesto que de su aplicación, se han localizado, no solo mineralizaciones radiactivas de interés económico, sino también mineralizaciones que, por lo reducido de sus manifestaciones en superficie, nos dicen del rigor de los métodos empleados para su localización.